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Development of Government Procurement Guidelines for Construction Products Containing Recovered Materials

Cal'span Corp, Buffalo, NY

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DEVELOPMENT OF GOVERNMENT PROCUREMENT
GUIDELINES FOR CONSTRUCTION PRODUCTS
CONTAINING RECOVERED MATERIALS

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ABSTRACT

The Resource Conservation and Recovery Act of 1976 (Public Law-94-580), under Section 6002, requires each federal procuring agency to "...procure items composed of the highest percentage of recovered material consistent with maintaining a satisfactory level of competition." In previous studies the U.S. Environmental Protection Agency identified construction products as an area in which increased use of recovered materials is possible.

The objective of this study was to acquire, interpret, and develop information on construction products containing recovered materials and to formulate possible guidelines for promulgation. Seven material categories were considered: iron and steel; aluminum; fly ash; paper; rubber; glass; and plastic. Manufacturing processes for selected construction products were reviewed and the potential for increased utilization of recovered materials was assessed. The report identifies candidate federal procurement guidelines for construction products made from iron and steel, aluminum, fly ash and rubber. For the paper, glass, and plastics categories the promulgation of procurement guidelines does not appear to be warranted at this time.

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Section 1

INTRODUCTION

The Resource Conservation and Recovery Act of 1976 (Public Law 94-580), under Section 6002, requires each federal procuring agency to "...procure items composed of the highest percentage of recovered material practicable consistent with maintaining a satisfactory level of competition." This requirement applies only to items for which the purchase price exceeds \$10,000, or where total purchases of the item in the preceding fiscal year exceeded \$10,000. The Act requires further that the U.S. Environmental Protection Agency prepare, and from time to time revise, guidelines for use by federal procuring agencies in complying with the requirements of Section 6002 of the Act. The Environmental Protection Agency has, through previous studies, identified construction and building products as an area in which reductions in the solid waste stream and increased use of recovered materials are possible.

The objective of this study (Contract No. 68-01-4789) was to provide EPA with information on construction products relevant to the development of federal procurement guidelines for promulgation under Section 6002(e) of the Act. Specific information of interest included: current and projected demand for products; amounts of recovered material currently being used in their manufacture; factors affecting recovered material use; the expected impacts of procurement guidelines on the amounts of recovered material consumed, on competition within the industry and on price and availability of products; and methods available for certifying the amounts of recovered materials contained in product shipments. The study was limited to the following material categories: iron and steel; aluminum; fly ash; paper; rubber; glass; and plastics.

Sources of data used in the study included published reports and articles, and numerous contacts with representatives of government agencies, industry, trade associations, professional societies, and universities.

The study identified several candidate procurement guidelines in the following categories: iron and steel; aluminum; fly ash; and rubber. These potential guidelines are discussed in the program summary that follows.

Section 2

SUMMARY

The Environmental Protection Agency, under Section 6002(e) of the Resource Conservation and Recovery Act (Public Law 94-540), must promulgate guidelines to be utilized by government procurement agencies in the purchase of designated products.

The objective of this program is to acquire, interpret, and develop information on construction products containing recovered materials and to formulate possible guidelines for promulgation. Specific information of interest includes product supply and demand, availability of recovered materials, and their current and potential future use in construction products. Other pertinent information relates to: (1) determining if construction products which contain varying quantities of recovered materials are meeting or can meet reasonable performance standards, and (2) providing mechanisms to enable suppliers to certify the recovered material content of the products. Recovered materials of interest in this program are grouped into the following seven categories:

1. Iron and steel
2. Aluminum
3. Fly ash
4. Paper
5. Rubber
6. Glass
7. Plastic

Two major objectives in the issuance of guidelines are the reduction in the solid waste stream and the conservation of scarce resources (material and energy). The attainment of the first objective does not necessarily insure attainment of the second objective, particularly when the use of waste material is restricted to a specific class of products (e.g., construction materials), as is the case in this study. It must be recognized that the use of recovered or waste materials in construction products does not necessarily represent the best use of such materials. They may, in some instances, replace earth materials, which are cheap and in plentiful supply, or other waste products.

Many construction products have always contained varying parts of recovered materials, e.g., construction products made of iron and steel or aluminum alloys, roofing felts, and wallboard. The problem then becomes mainly one of increasing the content of recovered materials in construction products.

The aforementioned guidelines would apply directly only to government procurement agencies which purchase construction products. In recent years, the value of federally owned construction programs has accounted for about 4 to 5 percent of total construction in the U.S. State and locally owned public construction programs, financed in varying degrees by the Federal Government, represented 18 to 20 percent of total construction.

Increased use of recovered materials only in construction materials employed in federally owned construction programs would obviously be of relatively little consequence. It would be expected, however, that the guidelines would be subsequently adopted for all public construction programs and would carry over to the private sector as well.

Section 6002 of Public Law 94-580 lists four requirements applicable to the procurement of items which contain recovered materials, namely:

1. A satisfactory level of competition must be maintained;
2. items must be available in a reasonable period of time;
3. items must meet performance standards; and
4. items must be available at a reasonable price.

The investigation and evaluation conducted indicated that the potential for the increased use of recovered materials exists in the iron and steel, aluminum, fly ash, and rubber categories. Possible guidelines for the four categories are presented in Table 2-1. Guidelines for the latter category should be held in abeyance until demonstration programs currently in progress are completed and evaluation results are published. The paper construction products category provides very limited opportunity for increasing the employment of recovered products due to their present extensive use. Further research, development and tests are needed before guidelines can be formulated for the enhanced use of recovered glass and plastic.

A screening rationale has been developed to facilitate the assessment of alternative uses of recovered materials and to assure that it is done in a consistent manner. The screening process is not intended to replace the criteria specified in the Public Law, but rather to provide a systematic procedure for selecting candidate concepts which are to be measured against the four criteria.

Four areas are examined in the screening process. These are:

1. Product performance
2. Economics
3. Conservation
4. Waste stream impact

TABLE 2-1. SUMMARY OF PROCUREMENT GUIDELINE ALTERNATIVES

RECOVERED MATERIAL/ APPLICATION	PRODUCT PERFORMANCE	ECONOMICS	CONSERVATION	WASTE STREAM
<u>IRON AND STEEL</u> * 1. Require quarterly reporting of recovered material use and set minimum level requirements by steel-making shop	a. No change	a. May reduce depletion allowance claims (1) b. May require some capital investments (1) c. End product cost may increase	a. Reduced ore and coal use b. Possible increased gas use; little change in oil consumption	a. Slight reduction in waste stream
2. Require that reinforcing bars be made in electric furnaces	a. No change	a. Probably no change	a. Very slight reduction in ore use b. Slight reduction in total energy use	a. Very slight reduction in waste stream
3. Set minimum recovered material requirements by shipment and by furnace type, e.g., BOF, > 30%	a. No change	Same as a, b, and c of alternative 1	Same as a and b of alternative 1 (2)	a. Slight reduction in waste stream

* Suggested guideline alternative

(1) Economic impact depends on minimum level of recovered material content mandated and how achieved, e.g., increased scrap use or use of sintered waste

(2) Reduced impact compared to alternative 1 because of smaller quantity of steel involved

TABLE 2-1. SUMMARY OF PROCUREMENT GUIDELINE ALTERNATIVES (Cont.)

RECOVERED MATERIAL/ APPLICATION	PRODUCT PERFORMANCE	ECONOMICS	CONSERVATION	WASTE STREAM
<u>ALUMINUM</u> *1. All construction products must contain at least 5% of recovered material	a. No change	a. No significant change; some companies may require added facilities	a. Small savings in virgin material	a. Slight reduction in waste stream
<u>FLY ASH</u> *1. Replace 10-40% of cement with fly ash in concrete for specific applications 2. Replace small amount of cement ($\leq 10\%$) with fly ash in concrete 3. Increase use of blended cements containing fly ash	a. Enhanced performance a. No change a. No significant change	a. Small investment by contractor (silo) b. Slightly lower end-product cost c. Reduces revenue of cement manufacturers Same as a, b, and c above a. Contractor may incur additional costs due to differing curing conditions b. Slightly higher end-product cost	a. Small savings in raw materials b. Small savings in energy Same as a and b above Same as a and b above	a. Moderate reduction in waste stream a. Significant reduction in waste stream a. Significant reduction in waste stream

* Suggested guideline alternative

TABLE 2-1. SUMMARY OF PROCUREMENT GUIDELINE ALTERNATIVES (Cont.)

RECOVERED MATERIAL/ APPLICATION	PRODUCT PERFORMANCE	ECONOMICS	CONSERVATION	WASTE STREAM
RUBBER				
*1. 20% ground rubber for selected applications	a. Final product (pavement) is enhanced	a. Some capital investment needed to prepare ground rubber b. Contractor requires special equipment for mixing asphalt and rubber; larger nozzles for spreading mixture c. End-product cost will increase	a. Some additional energy required for preparing ground rubber b. Further recycling capability is lost c. Minor saving in virgin material may result due to longer pavement life	a. Could result in moderate waste stream reduction
2. Small amount ($\leq 1\%$) in asphalt paving	a. No change	a. Significant capital investment needed for facilities to grind rubber b. New nozzles may be required for application of asphalt c. End-product cost will increase	a. Some additional energy required for preparing ground rubber b. Further recycling capability is lost c. No virgin material is saved	a. Could result in significant waste stream reduction

* Suggested guideline alternative

Note: Guidelines are contingent upon continued, favorable evaluation of on-going demonstration programs being conducted by the Federal Highway Administration

Section 3
CONCLUSIONS

GENERAL

- a. Recovered materials, particularly iron and steel scrap, waste paper, fly ash, and scrap aluminum, are being used rather extensively in the manufacture of construction products.
- b. Certification of the exact recovered material content of individual product shipments would pose a problem in nearly every product category. The problem could be alleviated to some degree by allowing certification of recovered material content either within certain specified ranges or on a "greater than" basis.
- c. Allowing or requiring certification of recovered material content on the basis of average use in production, rather than on a per shipment basis, is preferred. This eliminates some of the difficulties in ascertaining actual recovered material use in any given production run and at the same time can be expected to result in a greater increase in the use of recovered materials. Potentially, recovered material use would increase for all products produced in a given facility instead of only for government-purchased products, as might be the case if certification were required on a shipment basis.

IRON AND STEEL

- a. On the average, scrap consumption in all steelmaking furnaces in the U.S. constitutes approximately 44 to 45 percent of the total metal charged to the furnaces. For individual furnace types, consumption averages 45.7 percent for open-hearth furnaces, 28.9 percent for basic oxygen furnaces, and 97.7 percent for electric-arc furnaces.
- b. Most of the scrap consumed in steelmaking furnaces is home scrap. Purchased scrap, consisting of prompt industrial scrap and obsolete scrap, accounts for approximately 30 to 35 percent of the total scrap consumed in steelmaking.

- c. Scrap consumption in basic oxygen furnaces (BOF's) is limited to 30 percent of the metal charge under normal operating conditions. Increasing the use of scrap in BOF's requires preheating the scrap or superheating the molten pig iron.
- d. Recovered material use in steelmaking can be increased overall by increasing the use of sintered wastes (e.g., flue dusts, sludges) in the production of pig iron in blast furnaces.
- e. Theoretically, scrap consumption in open-hearth and electric furnaces can approach 100 percent of the metallic charge. While electric-arc furnaces generally operate near the theoretical limit, open-hearth furnaces seldom do. Because steel production in open-hearth furnaces is steadily declining, it is not considered worthwhile to develop a procurement guideline requiring increased use of scrap in open-hearth furnaces.
- f. Projections of the availability of iron and steel scrap made by scrap users and scrap suppliers differ sharply. The iron and steel industry anticipates a serious scrap shortage by the year 1982, while the scrap industry maintains that ample supplies will be available. This disparity is not considered of major importance in the context of procurement guidelines for the iron and steel category because the effect that procurement guidelines would have on scrap consumption is modest and less than the average year-to-year fluctuations in the consumption of purchased iron and steel scrap.
- g. Iron and steel foundry products are produced almost entirely from scrap. Consequently, little, if any, advantage would be gained by the promulgation of procurement guidelines that specified a minimum recovered material content.

ALUMINUM

- a. The recovery of secondary aluminum has shown a generally steady increase in recent years and in 1977 accounted for 26 percent of the domestic supply of new aluminum. This figure includes scrap generated in plants making end products (new scrap) and scrap recovered from metal that has been used by consumers (old scrap).

- b. Aluminum products used in public and private construction account for approximately 23 percent of total domestic aluminum production. In 1977, public construction utilized an estimated 300,000 tons of aluminum. This amount includes aluminum produced by both primary and secondary smelters.
- c. It is estimated that products manufactured by primary producers in 1977 contained 3 percent old scrap on the average. Government procurement guidelines requiring a minimum of 5 percent old scrap content in construction products would have resulted in an increase in scrap use of 21,000 tons in 1977, if applied to all construction, and 4,600 tons if applied to public construction only. The latter amount is only 1 percent of the total scrap (old and new) consumed by primary producers in 1977.
- d. Most aluminum construction materials are classified as wrought products and are largely manufactured by primary producers. Although secondary smelters appear to produce a sufficient quantity of aluminum to meet the demand for construction products in public construction, much of their output is not suitable for this purpose. Consequently, the impact of government procurement guidelines on secondary smelters would be small.

FLY ASH

- 1. Fly ash has been used in concrete construction for many years as a partial substitute for cement. Fly ash can provide performance characteristics which are highly desirable in selected construction projects, e.g., dam construction. The U.S. Corps of Engineers and TVA allow, and have recommended, its use in many projects.
- 2. There is sufficient variability in fly ash obtained from different sources, and even from a single source, to require careful testing prior to its use in cement or concrete. The U.S. Corps of Engineers requires such tests for each project where fly ash is used.
- 3. Small quantities of fly ash, e.g., less than 5 percent, could be added to almost all concrete without adversely affecting performance. Such use could result in a significant reduction in the waste stream. It would, however, also result in higher costs due to transport, storage and test requirements. This approach would represent primarily a fly ash final disposal method.

PAPER

- a. Waste paper and corrugated are used extensively in the manufacture of construction products. Specific products include: roofing felt, wallboard, cellulose insulation, insulating board, floor and roof decking, and wall paneling.
- b. For nearly all products, waste paper and corrugated are being utilized to the maximum extent possible consistent with the technical requirements of the production processes. In a number of cases, increasing the amounts of waste paper consumed would result in a decrease in the amounts of other solid wastes consumed, notably sawdust.
- c. Product specifications in this product category are based on performance. The industry's manufacturers employ a number of proprietary processes to produce the paper construction materials. Such processes utilize varying amounts or varying combinations of waste or recovered materials, making it impractical to require a minimum content of any one specific waste material.

RUBBER

- a. Blended mixtures of asphalt and ground automobile tires have been used successfully in highway paving applications. Mixtures containing 20 to 30 percent rubber, used either as seal coats or as stress-absorbing membrane interlayers over old pavement, have been shown to be effective in reducing reflective cracking in many locations.
- b. The use of asphalt-rubber mixtures in highway paving is not expected to produce beneficial results in all applications. Assuming that the performance of 10 percent of all the asphalt used in paving could be enhanced by the addition of waste rubber in amounts of 25 percent, it is estimated that such an application could consume 120 million discarded tires each year. Tires are discarded at the rate of 200 to 300 million per year.
- c. It is estimated that the use of ground rubber tires in paving asphalt in amounts ranging from 2 to 3 percent would consume all the tires discarded annually. Since waste rubber in such small amounts would not have any beneficial effect on pavement performance, such an application would serve primarily as a means of waste disposal.

GLASS

- a. A considerable amount of research and development activity is presently in progress which addresses various phases of recovered glass use in construction materials. This extends from programs concerned with glass separation and sorting to the use of ground glass in bricks. While some of these programs appear promising, none has reached the level of commercial practicability. A major economic obstacle is that the materials which would be replaced by glass are generally of low value and in plentiful supply.

PLASTIC

- a. Most plastic scrap that is segregated and uncontaminated is currently being recycled. On the other hand, only a small fraction of the mixed and contaminated scrap is being recovered and recycled, primarily because the cost of collecting, separating, and processing the scrap often exceeds the salvage value of the scrap or the cost of virgin material. Further, specifications for many plastic construction materials, such as most pipe, prohibit the inclusion of recovered plastic in the product.

Section 4
RECOMMENDATIONS

GENERAL

It is recommended that guidelines be developed at this time for construction products in the following material categories: iron and steel, aluminum, and fly ash. Specific recommendations are as follows:

- Iron and Steel - Require quarterly reporting of recovered material use and set minimum requirements by steelmaking shop.
- Aluminum - All construction products must contain at least 5 percent of recovered material.
- Fly Ash - Replace 10 to 40 percent of cement with fly ash in concrete for specific applications.

The issuance of guidelines for the use of rubber should be held in abeyance until the results from current demonstration projects become available.

Guidelines for paper construction products should not be issued. Extensive use is presently made of recovered materials in these products and guidelines may even prove counterproductive by substituting one waste product for another.

Recovered glass use in construction material should not be implemented until commercially feasible processes have been developed. This appears to be a number of years in the future.

No guidelines should be prepared at this time for recovered plastic use in construction materials. Such use is not current practice, generally because of the difficulty and cost of salvaging plastics and the prohibition of the use of recovered materials in many construction products.

AREAS FOR FURTHER INVESTIGATION

- a. An extensive education and publicity program is needed to familiarize federal, state, and local officials associated with preparing construction program specifications or material purchasing with the benefits of recommending the use of construction materials which contain recovered materials. This is particularly appropriate to the use of

fly ash in cement and potentially to the use of asphalt which contains ground rubber. A study should be made to formulate such a program and determine the best way to implement it.

- b. There is some evidence that the blended cements are used much more extensively in Europe than in the U.S. A study to determine the factors which account for the greater application of such cements, together with associated costs and benefits, is suggested
- c. A requirement for increased use of recovered materials in basic oxygen furnaces can be met in three ways: by preheating scrap, by increasing the recovered material content of the pig iron charged to the furnace, or by a combination of these. Further studies are needed of the technical and economic problems associated with these alternatives, i.e., the addition, where necessary, of preheating facilities at existing BOF's and the increased use of sintered wastes in blast furnaces
- d. No statistical series are compiled which measure the quantities of old scrap consumed by primary aluminum producers. Additional information is required on the quantities of old scrap primary producers can employ in the formulation of the variety of aluminum alloys used in construction materials and the types and availability of required scrap.

Section 5

METHODOLOGY

INTRODUCTION

This section describes the methodology used in formulating and evaluating candidate government procurement guidelines for construction products in the seven material categories identified in the Introduction, Section 1. Discussed are the general approach taken, the sources of data used, and the criteria for evaluating the effectiveness and acceptability for specific candidate guidelines.

APPROACH

For each material category, the amounts and types of construction products used in recent years in construction programs in the U.S. were determined. Generally, the quantities for major construction products were broken down into three separate categories: (1) federally owned construction, (2) state and local construction, supported in varying degrees by federal funds, and (3) private construction. In most cases, the impact of any given procurement guideline on recovered material utilization was assessed in terms of the quantities of products represented by all public construction, that is, by the sum of categories 1 and 2 above.

For each material category, the manufacturing processes were reviewed to determine the extent to which recovered materials are already being used in the production of the associated construction products. Of particular interest were the effects of the quality and quantity of recovered material on product performance and the changes in production procedures required to allow the levels of recovered material content to be increased. Also of interest were those factors that traditionally have inhibited the use of greater amounts of recovered materials in production, including economic and institutional factors, as well as technical factors. Another area of concern was the feasibility of requiring manufacturers and/or suppliers of construction products to certify the amounts of recovered material contained in the shipments.

After reviewing the information acquired for each product type, various tentative guideline alternatives were postulated and then evaluated in terms of their effects on the following factors: product performance, selling price, competition within the industry, and delivery schedules. If, for any given alternative, the evaluation showed that any one of these factors would be severely affected in an

adverse way, that alternative was eliminated. Generally, product performance was considered first in the evaluation since this is considered to be the single most important factor. Any proposed guideline must not compromise the integrity of the product with respect to those factors that affect its overall performance, such as strength, hardness, corrosion and wear resistance, fire retardant properties, and stability.

DATA SOURCES

At the start of the program, a literature search was made to identify reports, journal articles, books, conference proceedings and other sources of published information relevant to the study. References to specific publications are made throughout the text of the report. A bibliography is included at the end of the report.

While published data provided a substantial fraction of the desired background and input information, it was recognized at the beginning of the study that direct contact would be required with representatives of government agencies, industry, trade associations, technical societies, and universities to obtain current assessments of demands, trends, industry practices, and potential obstacles to increased use of recovered materials in the manufacture of construction products. Accordingly, numerous organizations were contacted in the course of the program. These are listed in Appendix A.

To facilitate the acquisition of information from government agencies on procurement practices and from trade associations on recovered material use, a list of Information Needs was prepared for each of these two groups. Copies of the Information Needs lists are given in Appendix B. In addition to an Information Needs list, copies of the Work Statement and the Resource Conservation and Recovery Act were sent to each agency and trade association contacted.

Section 6
PUBLIC CONSTRUCTION PROGRAMS

INTRODUCTION

The magnitudes and types of construction programs supported by the Federal Government, both directly and indirectly through grants and loans, provide one measure of the potential impact of guidelines for the use of construction materials which contain recovered materials. The construction program descriptions also indicate, in gross form, the types and quantities of construction materials employed.

PUBLIC AND PRIVATE CONSTRUCTION

General

The Federal Government has never produced a capital budget, i.e., one in which capital or investment types of programs are financed separately from current expenditures.

A recent Office of Management and Budget Analysis¹ divides budget outlays between those of an investment or "capital" nature and those devoted to operating or "current" purposes. A distinction is made between "direct" investments and "additions to state and local assets." The budget outlays are categorized by cognizant government agencies.

Pertinent information¹ which refers to construction activities is presented in Table 6-1 for FY'77, FY'78, and FY'79. FY'77 data represent actual allocations; FY'78 and FY'79 data represent estimates. The latter are adjusted to 1977 dollars assuming 8% annual inflation.

The U.S. Department of Commerce publishes public and private construction information in its "Construction Reports" series. The value of new construction put in place is presented by type of construction, i.e., buildings, highways, military facilities. Data for FY'73-FY'77² are shown in Table 6-2. Note that "State and Locally Owned" construction programs listed in Table 6-2 represent total program allocations which include Federal Government contributions and assistance.

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1. "Investment, Operating, and Other Budget Outlays," Special Analysis D, Office of Management and Budget, January 1978.
 2. "Construction Reports, New Construction Put in Place," U.S. Department of Commerce, March 1978.

TABLE 6-1. FEDERAL AND FEDERALLY SUPPORTED CONSTRUCTION PROGRAMS (IN 1977 DOLLARS - MILLIONS)*

	FISCAL YEAR		
	1977	1978	1979
National Defense			
Military Construction	\$ 1,767	\$ 1,649	\$ 1,575
Family Housing	286	228	87
Atomic Energy Defense Activities	218	300	291
Subtotal	2,271	2,177	1,953
Additions to Federal Assets			
To State and Local Govts. (largely DC)	30	166	60
Public Works			
Dept. of Agriculture (largely Forest Service)	188	314	333
Corps of Engineers	1,442	1,389	1,265
Dept. of Energy (largely energy supply)	547	967	938
HEW	140	233	216
Dept. of the Interior			
Bureau of Reclamation	603	512	397
National Park Service	66	107	131
Bureau of Indian Affairs	125	131	133
Other	30	64	81
DOT (largely FAA)	274	264	217
NASA	105	122	133
VA	234	291	341
TVA	1,204	1,387	1,236
Other Agencies	201	281	200
Subtotal	5,159	6,062	5,621
Additions to State and Local Assets			
Appalachian Regional Dev. Program	213	235	228
Disaster Relief	168	107	162
Dept. of Agriculture (largely rural development and construction operations)	259	393	325
Dept. of Commerce (largely public works programs)	805	2,391	1,904
Dept. of the Interior (largely recreational resources)	281	322	394
HUD (largely community development grants)	3,146	3,140	2,846
DOT			
FAA grants-in-aid for airports	335	500	487
Fed. Highway Adm. (largely federal-aid highways)	5,884	6,163	6,341
UMTA	1,043	1,109	1,174
EPA Construction Grants	3,530	3,829	4,017
Other Agencies (largely energy conservation)	747	427	478
Subtotal	16,417	18,616	18,356
Total Federally Owned	7,460	8,405	7,634
Total Additions to State and Local Assets	16,417	18,616	18,356
Grand Total	\$23,877	\$27,021	\$25,990

*Source: "Investment, Operating and Other Budget Outlays," Special Analysis D, Office of Management and Budget, January 1978.

TABLE 6-2. VALUE OF NEW CONSTRUCTION PUT IN PLACE IN
THE U.S. (IN 1977 DOLLARS - MILLIONS)*

	1973	1974	1975	1976	1977
Federally Owned Buildings					
Housing	\$ 131	\$ 190	\$ 196	\$ 155	\$ 166
Industrial	606	766	918	971	1,143
Educational	57	47	16	6	13
Hospital	156	170	249	288	380
Other	380	331	296	268	340
Subtotal	1,330	1,504	1,674	1,689	2,041
Highways and Streets	268	257	314	316	(N/A)
Military Facilities	1,166	1,185	1,390	1,508	1,476
Conservation and Development	1,955	2,246	2,635	2,828	2,998
Miscellaneous	132	100	90	81	113
Total	4,851	5,293	6,105	6,421	6,971
State and Locally Owned Buildings					
Housing	810	816	472	473	720
Educational	6,590	7,263	7,745	6,269	5,415
Hospital	846	1,068	1,483	1,489	1,269
Other	3,419	4,339	3,879	3,304	3,003
Subtotal	11,665	13,487	13,580	11,526	10,407
Highways and Streets	10,237	11,808	10,547	9,439	8,832
Conservation and Development	358	495	618	894	764
Other					
Sewer System	1,954	2,681	4,801	5,286	5,391
Water Supply Facilities	1,068	1,381	1,765	1,595	1,753
Miscellaneous	2,372	3,189	3,255	2,820	2,914
Subtotal	5,394	7,252	9,821	9,701	10,058
Total	27,654	33,042	34,566	31,560	30,061
Total New Construction — Private	105,412	100,166	93,623	109,500	132,701
Total New Construction — Federally Owned	4,851	5,293	6,105	6,421	6,971
Total New Construction — State and Locally Owned	27,654	33,042	34,566	31,560	30,061
Grand Total	\$137,917	\$138,501	\$134,293	\$147,481	\$169,734

N/A = Not available but estimates are included in totals.

*Source: "Construction Reports, New Construction Put in Place",
U.S. Department of Commerce, March 1978.

A limited comparison is possible between Tables 6-1 and 6-2 for FY'77. For example, total federally owned construction is valued at \$7,460 million in Table 6-1 versus \$6,971 million in Table 6-2, a difference of less than 7 percent. An earlier U.S. OMB Special Analysis for FY'73³ reports federally owned construction valued at \$7,207 million* for FY'73 compared to \$4,851 million in Table 6-2. The same report lists total public expenditures for construction in FY'73 as \$32,450 million* versus \$32,415 million based on Table 6-2 data. It is concluded that the information presented in Tables 6-1 and 6-2 represent different descriptions of the same data base, and this assumption is made in the construction procurement analysis and projection which follow.

The relationships between private, public federally owned, federally assisted and state and locally owned construction programs are shown in Table 6-3. Public construction represented about 26 percent of total U.S. construction between FY'73 and FY'78. Federally owned construction activities accounted for about 4 percent and remained constant throughout this period.

Considering only public construction, federally owned construction increased slightly from 15 percent in FY'75 to 19 percent in FY'77. A further breakdown of public construction into its three major funding sources shows states and localities assuming a somewhat larger share of total expenditures in FY'77 than they did in FY'73. Finally, current and estimated immediate future construction allocations indicate that, of the total federal construction budget, about 30 percent is allocated to federally owned construction and the remainder forwarded to states and localities to assist in local construction programs.

Although the data provide information on the total state and local allocations to public construction (i.e., the differences between total public and total federal construction in Figure 6-1), the total value of construction programs which receive federal assistance cannot be determined. This is because some programs may be financed solely by state and local governments. These programs are believed to be relatively small. It may be assumed, however, that localities will use the same specifications for their own construction programs as apply to federally assisted construction programs.

It will be assumed for the purpose of this study that all public construction will be impacted by potential federal guidelines, recognizing, however, that the resultant values regarding amounts of building materials involved in the programs represent the upper bound.

3. "Study of the Feasibility of Requiring Secondary Materials in Federal Construction," Resource Planning Associates, Inc., January 1975.

* Adjusted to 1977 dollars based on U.S. Dept. of Commerce Composite Index

TABLE 6-3. RELATIONSHIPS BETWEEN PRIVATE/PUBLIC AND FEDERALLY OWNED/STATE AND LOCALLY OWNED CONSTRUCTION PROGRAMS

	1973	1974	1975	1976	1977	1978	1979
Total Construction							
% Private	76	72	70	74	78		
% Public	24	28	30	26	22		
% Federally Owned	4	4	5	4	4		
% State and Locally Owned*	20	24	25	22	18		
Total Public Construction							
% Federally Owned	15	14	15	17	19		
% State and Locally Owned*	85	86	85	83	81		
Total Public Construction							
% Federally Owned	22**				19		
% Federal Additions to State and Locally Owned	51**				44		
% State and Locally Owned	27**				37		
Total Federal and Federally Assisted Construction Programs							
% Federally Owned	22**				30	29	28
% Federal Additions to State and Locally Owned	78**				70	71	72

* Includes Federal Government additions to state and locally owned construction.

**Source: "Study of the Feasibility of Requiring Secondary Materials in Federal Construction," Resource Planning Associates, Inc., January 1975.

Projection of Construction Activities for FY'78 Through FY'85

Estimated U.S. construction for FY'78-FY'85 is shown in Figure 6-1. The least-squares method was used to determine the trend lines.

Although total U.S. construction is projected to rise substantially over the next 7 years, most of the increase is attributed to the private sector. Only very modest increases are foreseen for the public sector, averaging 2 to 3 percent.

CONSTRUCTION MATERIALS EMPLOYED IN PUBLIC CONSTRUCTION

The construction materials of primary concern in this study are:

Iron and Steel

- Bars (primarily concrete reinforcing)
- Cast iron pipe
- Structural shapes, plates, and sheets

Aluminum

Fly Ash

- Road and construction fill
- Road base stabilizer
- Asphalt paving filler
- Concrete additive and cement manufacture
- Lightweight aggregate

Paper

- Construction paper (e.g., roofing felt)
- Insulation and insulating board
- Hardboard

Rubber (from waste tires)

- Crumb with asphalt in pavement and paving blocks

Glass

- Ceramic bricks (traditional facing bricks)
- Glasphalt (used as an aggregate in asphalt mixtures)
- Glas-polymer concrete (e.g., as used in sewer pipes)
- Foamed lightweight aggregate in concrete

Plastic

- Pipes (including agricultural drainage tubing)

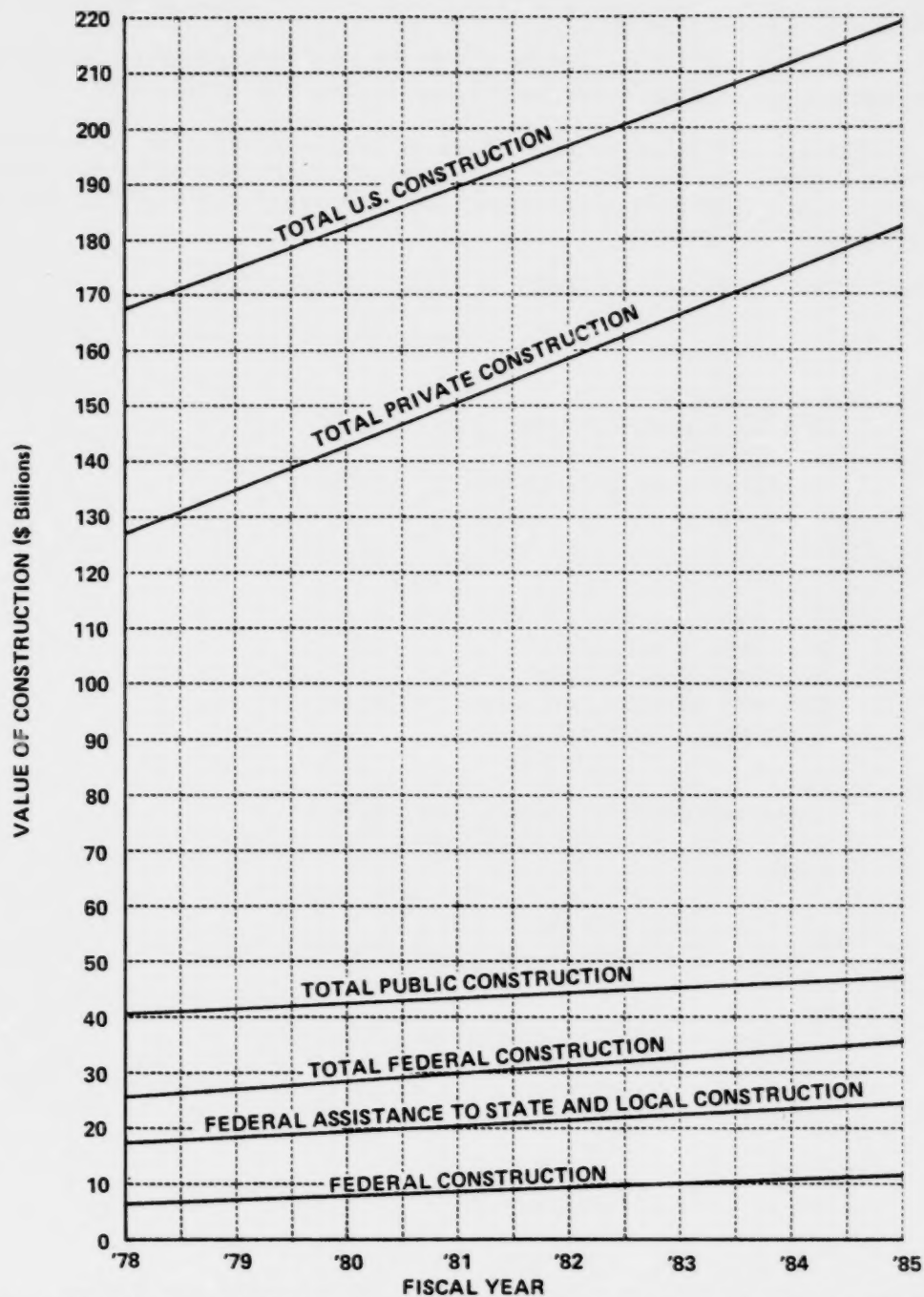


Figure 6-1 ESTIMATED CONSTRUCTION ACTIVITY, FY78 - FY85 (VALUES IN 1977 DOLLARS)

PROCUREMENT PRACTICES

The comments following are based on discussions and correspondence with a number of government agencies which support significant construction activities. These include the Corps of Engineers, TVA, and the U.S. Department of Transportation.

The agencies indicated that there is no single person or group responsible for the purchase of construction materials. In most cases, this appears to be the function of the prime contractor or subcontractors who follow the specifications applicable to their contractual obligations. In some instances, however, the Government itself is the direct purchaser of the construction material.

Regardless of whether or not the Government is engaged in the direct purchase of construction materials, its greatest impact on the use of recovered materials in construction is through its preparation and issuance of specifications. Specifications describe the technical requirements for materials, products, and services. Specifications are an integral part of a purchase contract. GSA is responsible for the acceptance and publication of specifications other than military specifications.

Specifications frequently refer to Federal and industry standards. Standards establish engineering or technical limitations and testing procedures, and circumscribe applications for materials, processes, methods, and designs.

Recent years have seen a trend toward performance specifications. Such specifications generally do not exclude the use of recovered materials in construction products. At the same time, however, such specifications do not mandate the use of construction products which contain recovered materials or necessarily encourage their utilization.

The major significance of Government specifications results from their inclusion in federally supported state and local construction programs and their adoption in part or in total by the private sector. These are in addition to federally owned construction programs.

There appears to be an ambivalence among engineers and contractors regarding the use of construction products which contain recovered materials. Certainly, this is not a new concept. For example, reinforcing bars made from steel produced in electric furnaces are used extensively. Such bars are made entirely from old and new scrap. At the same time, highway engineers appear to hesitate to use flyash or slag in concrete mixtures, although small additions will not alter performance in any way. The reasons cannot be readily defined.

Possibly slightly higher costs may be one consideration. Equally important may be possible blame in case of product failure, even though the failure may not have been caused by the addition of the recovered materials.

Necessary steps to further the use of construction materials which contain recovered materials may include specific reference to such materials in the specifications as well as a rigorous education and information program designed to familiarize contractors and engineers with such materials.

Section 7

IRON AND STEEL PRODUCTS

INTRODUCTION

Iron and steel are used in virtually every phase of modern life. Major use, however, is concentrated in three areas: transportation, construction, and machinery. The purpose of this section is to identify the use of iron and steel products in construction, particularly in federally owned and other public construction programs.

Iron and steel products are generally grouped into two main categories: steel mill products and foundry products. Within the mill products category, those products that are used in substantial quantities in construction include: structural shapes (e.g., beams, channels, and angles); reinforcing bars; plates; hot rolled sheets; galvanized sheets and strip; hot rolled bars; and steel piling. Of the foundry products used in construction, cast iron pipe is probably the largest product group, consisting of cast iron soil pipe and cast iron pressure pipe.

U.S. DEMAND

The total U.S. demand for iron and steel products, as well as demand by major use categories, is presented in Table 7-1 for the 1969 to 1977 time frame. Total demand fluctuated considerably, reaching a peak in 1973 of 142.5 million short tons, experiencing a sharp decline in 1975, and recovering to the 1969 level in 1977.

Construction use of iron and steel accounted for about 25% of total demand, annual percentages having varied between 24 and 29% which represent about 30 to 40 million short tons of iron and steel.

USE IN CONSTRUCTION

There is no statistical series which identifies the types and quantities of iron and steel products used in construction. Table 7-2 represents an attempt to create a series of this type. It is composed of iron and steel production and shipment data of items which are known to be used extensively (although not necessarily exclusively) in construction.

Plates and structural shapes are the dominant items and account for about one-half of the iron and steel tonnage used in construction. Other significant items are concrete reinforcing bars, galvanized sheets, cast iron pipe, and fabricated steel products.

TABLE 7-1. U.S. DEMAND PATTERN FOR IRON AND STEEL
(MILLION SHORT TONS, IRON OR STEEL)*

	1969	1970	1971	1972	1973	1974	1975	1976	1977
U.S. Demand	126.5	116.9	108.1	124.9	142.5	138.4	104.1	117.8	126.1
Transportation	30.8	26.3	29.0	30.2	42.2	37.7	29.5	38.0	40.2
Construction	30.2	29.0	27.9	29.7	40.4	37.9	28.2	30.3	32.0
Machinery	22.0	20.4	19.4	21.6	28.5	29.3	21.0	23.7	25.3
Cans and Containers	7.9	8.5	7.9	7.3	8.9	9.4	6.7	8.0	8.1
Oil and Gas Ind.	5.2	4.9	5.1	5.6	7.8	8.3	7.2	6.8	8.4
Appliances and Equipment	6.2	6.0	5.7	6.4	8.5	8.1	5.3	6.5	7.2
Other	24.2	21.8	13.1	24.1	6.2	7.7	6.2	4.5	4.9
% Construction	23.9	24.8	25.8	23.8	28.4	27.4	27.1	25.7	25.4

*Source: "Iron and Steel," MCP-15 Mineral Commodity Profiles, Bureau of Mines, U.S. Department of the Interior, July 1978.

TABLE 7-2. ESTIMATED USAGE OF IRON AND STEEL CONSTRUCTION MATERIALS
(1,000 SHORT TONS)*

	1974	1975	1976	1977
Concrete Reinforcing Bars	5,089	3,666	3,876	4,179
Galvanized Sheets	6,105	3,720	5,180	5,657
Cast Iron Pipe				
Pressure	1,958	1,255	1,334	1,605
Soil	774	594	658	682
Fabricated Steel Products	4,566	4,335	3,719	3,486
Plates and Structural Shapes	18,200	17,531	18,031	11,900
Piling	662	424	330	347
Total	37,354	31,345	33,128	27,854

*Source:

"Iron and Steel," MCP-15 Mineral Commodity Profiles, Bureau of Mines, U.S. Dept. of the Interior, July 1978.

"Iron and Steel," A Chapter from Mineral Facts and Problems, 1975 Edition, Bureau of Mines Preprint from Bulletin 667, U.S. Dept. of the Interior.

"Steel Mill Products," Current Industrial Reports, MA-33B(76)-1, issued September 1977, Bureau of the Census, U.S. Dept. of Commerce.

"Iron and Steel Products: Shipments, Bookings and Backlog," Bureau of Mines, U.S. Dept. of the Interior, January/February 1978.

USE IN PUBLIC CONSTRUCTION

As indicated above, statistical information relating iron and steel products to construction programs is lacking. The exception is a data series compiled and published by the Concrete Reinforcing Steel Institute for apparent rebar usage by construction markets.

Rebar Usage

Shipments/use data of concrete reinforcing bars are available from two sources: the Bureau of the Census⁴ and the Concrete Reinforcing Steel Institute⁵. Comparable data for 1975 and 1976 are shown below.

Reinforcing Bars (1,000's of short tons)

	<u>Shipments</u>	<u>Apparent Use</u>
1975	3,666	3,800
1976	3,876	4,054

The data sets show close correspondence.

The CRSI data provide a breakdown of rebar usage by construction markets. As shown in Table 7-3, the categorization permits the distinction between public and private construction activities. The construction markets which comprise public construction are:

- Heavy construction
- All paving
- Bridges
- Public buildings

Note that only heavy construction includes some private construction among these categories.

Between 1970 and 1976, total public construction utilized approximately 58% of the total U.S. production of concrete reinforcing bars. The quantities of reinforcing bars employed in various public construction programs between 1973 and 1976 are shown below⁵.

4. "Iron and Steel Products: Shipments, Bookings and Backlog," U.S. Department of Commerce, Bureau of the Census, January/February 1978.

5. "Concrete Reinforcing Steel Institute 11-Year Statistical Report-Rebar Usage (1966 Through 1976)," published by Concrete Reinforcing Steel Institute, Chicago, Illinois, February 23, 1978.

TABLE 7-3. CONSTRUCTION MARKETS LISTED BY CRSI CATEGORIES*

APARTMENTS, HOTELS, MOTELS

High-rise apartments
Low-rise hotels and motels
High-rise hotels and motels

HEAVY CONSTRUCTION

Sewerage and waste disposal
Water supply
Dredging and drainage
Harbor and waterfront
Dams
Railroads, excluding buildings
Defense facilities
Irrigation canals, etc.
Other nonbuilding
Utilities, power, etc.
Oil, gas wells
Mining, quarrying
Miscellaneous

ALL PAVING

State Highways
Local urban streets
Local rural roads
Airports, excluding buildings

BRIDGES

State Highways
Local urban streets
Local rural roads

PUBLIC BUILDINGS

Elementary schools
High schools
Combination classroom buildings
Industrial, vocational and trade schools
College and universities
Other college and school buildings
Dormitories
Public administration and service buildings
Religious buildings
Low-rise hospitals
High-rise hospitals
Social, cultural, recreational buildings
Transportation and terminal buildings

INDUSTRIAL AND COMMERCIAL

Stores and miscellaneous commercial
Low-rise office buildings
High-rise office buildings
Parking buildings and lots
Commercial garages, service stations
Commercial warehouses and terminals
Industrial buildings, industrial warehouses
Clubs, lodges, theaters
Farm

ALL OTHER USES

One family houses
Two family houses
Low-rise apartments
Sidewalks
Driveways
Masonry
Retail cement sales
Etc.

*Source: PCA Economic and Market Research Department

Quantity of Reinforcing Bars (1,000 short tons)

	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>
Heavy construction	1,355	1,474	1,204	1,450
Paving and Bridges	680	568	466	307
Public Buildings	713	790	645	687
Total Public Construction	2,748	2,832	2,315	2,444

The above data are correlated with information in Table 6-2 to derive the quantities of reinforcing bars used per million dollars of public construction programs presented below.

Tons of Reinforcing Bars/\$Million of Public Construction

	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>Average</u>
Heavy Construction	152	131	83	97	116
Pavings and Bridges	65	47	43	31	47
Public Buildings	55	53	42	52	41
Total Public Construction	85	74	57	64	70

Highways and streets construction values listed in Table 6-2 were assumed to include bridges. All construction values except highways/streets and buildings were assigned to the "Heavy Construction" category.

Variations in the annual usage of reinforcing bars per million dollars of construction can be due either to changes in construction techniques employed, to differences in construction programs undertaken, or to a combination thereof. The average calculated values, however, are believed to provide reasonable reinforcing bar use factors for estimating the employment of reinforcing bars in public construction in the near future.

Uses of Other Iron and Steel Products

Public construction programs generally involve relatively large projects. Consequently, it is believed that the tonnage of iron and steel construction materials is relatively greater in public than in private construction programs when measured in terms of either tonnage/project or tonnage/dollar expended.

To illustrate the above, the value of public construction as a percent of total construction is compared with apparent rebar use

in public construction as a percent of total apparent rebar use in construction for the 1973-1976 time period.

	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>
% Value Public of Total Construction	24	28	30	26
% Apparent Rebar Use in Public Construction of Total Rebar Use	51	53	61	60

It is evident that apparent rebar use in public construction programs was about twice as great as would have been expected if public and private construction programs were essentially similar.

The evidence suggests that public construction utilizes more than its proportionate share of iron and steel construction materials. Apparent rebar use probably represents the upper limit, recognizing the general purposes for which rebars are employed.

Here, it will be assumed that public construction consumes 30-50% of the total material tonnages, other than rebars, listed in Table 7-2. Application of these bounds yields the tonnages listed in Table 7-4. The average annual use of iron and steel materials (other than rebars) is estimated to have amounted to about 11,000,000 short tons.

Estimated short tons of iron and steel construction materials (other than rebars) installed per million dollars of public construction are shown below.

1974	250-420
1975	210-340
1976	230-380
1977	200-320
Average	290

MANUFACTURING PROCESSES

Steelmaking Processes

In steelmaking, pig iron, scrap, or a mixture of the two, are converted into steel by a refining action that lowers the carbon and silicon levels and removes impurities such as sulfur and phosphorus. The oxygen level in the molten steel is neutralized by adding deoxidizing agents in controlled amounts. In the United States today, there are three major steelmaking processes in use: the open-hearth process, the electric-arc process, and the basic oxygen process. Of particular interest to the present study are the amounts of recovered material that can be used in each process without degrading the quality of the

**TABLE 7-4. ESTIMATED USE OF IRON AND STEEL IN PUBLIC CONSTRUCTION
(OTHER THAN REBARS) (1,000 SHORT TONS)**

	1974	1975	1976	1977
Galvanized Sheets	1,800-3,100	1,100-1,900	1,600-2,600	1,700-2,800
Cast Iron Pipe				
Pressure	6000-1,000	400-600	400-700	500-800
Soil	200-400	200-300	200-300	200-300
Fabricated Steel Products	1,400-2,300	1,300-2,200	1,000-1,700	1,000-1,700
Plates and Structural Shapes	5,500-9,100	5,300-8,800	5,400-9,000	3,600-6,000
Piling	200-300	100-200	100-200	100-200
Total	9,700-16,200	8,400-14,000	8,700-14,500	7,400-11,800

final product. To understand the limitations of the three processes with respect to the utilization of recovered material, it is worthwhile to review briefly how each process operates.⁶

Open-Hearth Process

The open-hearth process has been in use in the U.S. since the 1870's. In this process, the steel is produced in a shallow bath which is heated by flames that pass over the top from one end of the bath to the other. Heat in the gases exhausting from the side opposite the burners is recovered by regenerative chambers consisting of a checkerwork of brick. The direction of the flames is reversed in alternate cycles, and the heat stored in the regenerative chambers is used to preheat the combustion air and sometimes the fuel. Natural gas, coke-oven gas, and liquid fuels are the common fuels used.

6. The Making, Shaping and Treating of Steel, Ninth Edition, Harold E. McGannon, ed., United States Steel Corporation, 1971.

There are two different types of open-hearth processes in use: the acid open-hearth process and the basic open-hearth process, the major differences being in the operation and raw materials used for each. Also, there are differences in construction of the furnace, primarily in the fact that the bottom and banks of the basic open-hearth furnace consist of chemically basic materials whereas the bottom and banks of the acid open-hearth furnace are lined with silica brick and sand. While basic open-hearth furnaces are the more widely used of these two furnace types, the reliance on open-hearth furnaces in general has been declining steadily since the introduction of basic oxygen furnaces in the United States in the mid 1950's.

In basic open-hearth furnaces, there is considerable flexibility in the charge that can be used. However, the metal charge will depend to a large extent on the facilities that are available at the same location. In an integrated steel mill having a blast furnace, the metallic charge to the open-hearth furnace generally consists of 45 to 80 percent molten pig iron, the remainder being steel scrap and possibly some solid pig iron. Iron ore is added as necessary to control the carbon content of the bath, generally in decreasing amounts as the scrap ratio increases. If molten pig iron is not available, the open-hearth furnace can be operated using a metallic charge of solid steel scrap and solid iron. The open-hearth furnace can also be operated using a metallic charge of all solid steel scrap, but such operation requires considerable skill and is not commonly practiced in the industry.

At the start of a heat, limestone is charged first, usually in quantities of 5 to 8 percent of the total metallic charge. The limestone is then covered with iron ore followed by scrap, or with scrap directly if no iron ore is used. The melting period begins as soon as the scrap is charged. If the charge is to include molten pig iron, the latter would be added after the scrap has begun to melt and is sufficiently oxidized. As the melt progresses, the lime rises and a slag forms on the surface of the molten bath. At the conclusion of the melt, the steel is tapped from the furnace into a ladle.

In 1970, there were 408 open-hearth furnaces operating in the U.S., with capacities per heat ranging from 40 to 600 short tons of steel, although the capacities of over 90 percent of the furnaces fell in the range of 130 to 400 tons per heat. A 600 ton heat requires up to 10 hours to process, whereas smaller heats require approximately 5 hours.

Electric-Arc Process

Electric-arc steelmaking furnaces came into use in the United States shortly after the turn of the century. In electric-arc furnaces, the metal is heated by the radiation generated by arcs passing between adjacent electrodes (indirect-arc heating) or between electrodes and the metal (direct-arc heating). Arc furnaces based on direct arc heating are the most common type in use today in the steel industry.

A typical arc furnace consists of a cylindrical shell into which the scrap metal is charged. Above the shell are positioned two or more electrodes fastened to control mechanisms to allow the elevations of the electrodes to be adjusted as necessary to maintain the arc during melting and refining. The metallic charge generally consists of nearly 100 percent cold steel scrap, although hot pig iron and pre-reduced pellets can also be used. With proper control of the quality of the input scrap, nearly all grades of steel can be produced in electric-arc furnaces.

Electric-arc furnaces have the advantage of lower capital cost per ton of steel produced. They are particularly attractive in areas where electric power cost is low and steel scrap is plentiful. Small electric furnace plants, known as minimills, have been established in various areas in the U.S. where it is uneconomical to build and operate an integrated steel mill. Generally, these minimills produce the smaller and lighter types of mill products, such as bars.

In 1970, there were a total of 284 direct-arc electric steel-making furnaces operating in the United States with capacities ranging from 1 to 400 tons, although only four of the furnaces had capacities over 200 tons. A 200-ton capacity electric-arc furnace requires about 5 hours to produce a heat.

Basic Oxygen Process

The basic oxygen steelmaking process was introduced into the United States on a commercial basis in the mid-1950's. In this process, the metallic charge consists of molten pig iron and cold scrap, usually in the ratio of about 70 percent or more pig iron and 30 percent or less scrap. The amount of cold scrap that can be used is limited because the heat required to melt the scrap is supplied by the molten iron. If the ratio of molten iron to cold scrap is too low, there will be insufficient heat available to maintain the melt at the required temperature. The scrap fraction can be increased, however, by heating the scrap prior to charging.

A typical basic oxygen furnace (BOF) consists of a barrel-shaped vessel lined with chemically basic refractories and supported such that it can be tilted about a horizontal axis. During charging, the furnace is tilted and cold scrap is introduced, followed by molten pig iron. After charging, the furnace is returned to the upright position and an oxygen lance is lowered into the furnace to begin the refining operation. Within a few seconds after the flow of oxygen begins, reactions with impurities in the charge commence. When the oxygen blow is completed, the furnace is tilted, the temperature of the melt is measured, and a sample of the steel is taken for chemical analysis. Adjustments in temperature are made by adding scrap or limestone as a coolant, or by reinserting the oxygen lance and blowing oxygen to raise the temperature. When the proper chemistry and temperature are attained, the furnace is tilted and the steel is tapped into a teeming ladle. Alloying constituents are added to the ladle during the tapping operation. From the ladle, the steel is poured into ingot molds or transferred to the continuous caster.

In 1970, there were a total of 74 basic oxygen furnaces operating in the United States with capacities ranging from about 50 to 350 tons per heat. The capacities of approximately 50 percent of these furnaces fell in the 100 to 200 ton range. A 300 ton basic oxygen furnace can complete a heat in 45 minutes. The reduced time per heat over open-hearth and electric furnaces is an important advantage of the basic oxygen furnace. A disadvantage is that it cannot be operated independently of a source of hot metal (i.e., molten pig iron).

Steel Production by Furnace Type

The amounts of raw steel produced in the U.S. annually by each of the three steelmaking processes are given in Figure 7-1 for the years 1969 through 1977. Total raw steel production is shown at the top of the figure. The trend in the relative importance of each steelmaking process for the same period is better illustrated in Figure 7-2, which shows production by individual process expressed as a percentage of total U.S. raw steel production. The figure illustrates the steady decline in the reliance on open-hearth furnaces and the increased importance of the basic oxygen and electric furnaces. The production figures for 1978 are expected to show a continuing increase in the percentage of raw steel made in electric furnaces.

Steel Processing and Distribution

The function of each of the three steelmaking processes described above is to produce molten steel of the desired properties. This section provides a brief description of how the molten steel is transformed into the products of interest to this study--namely,

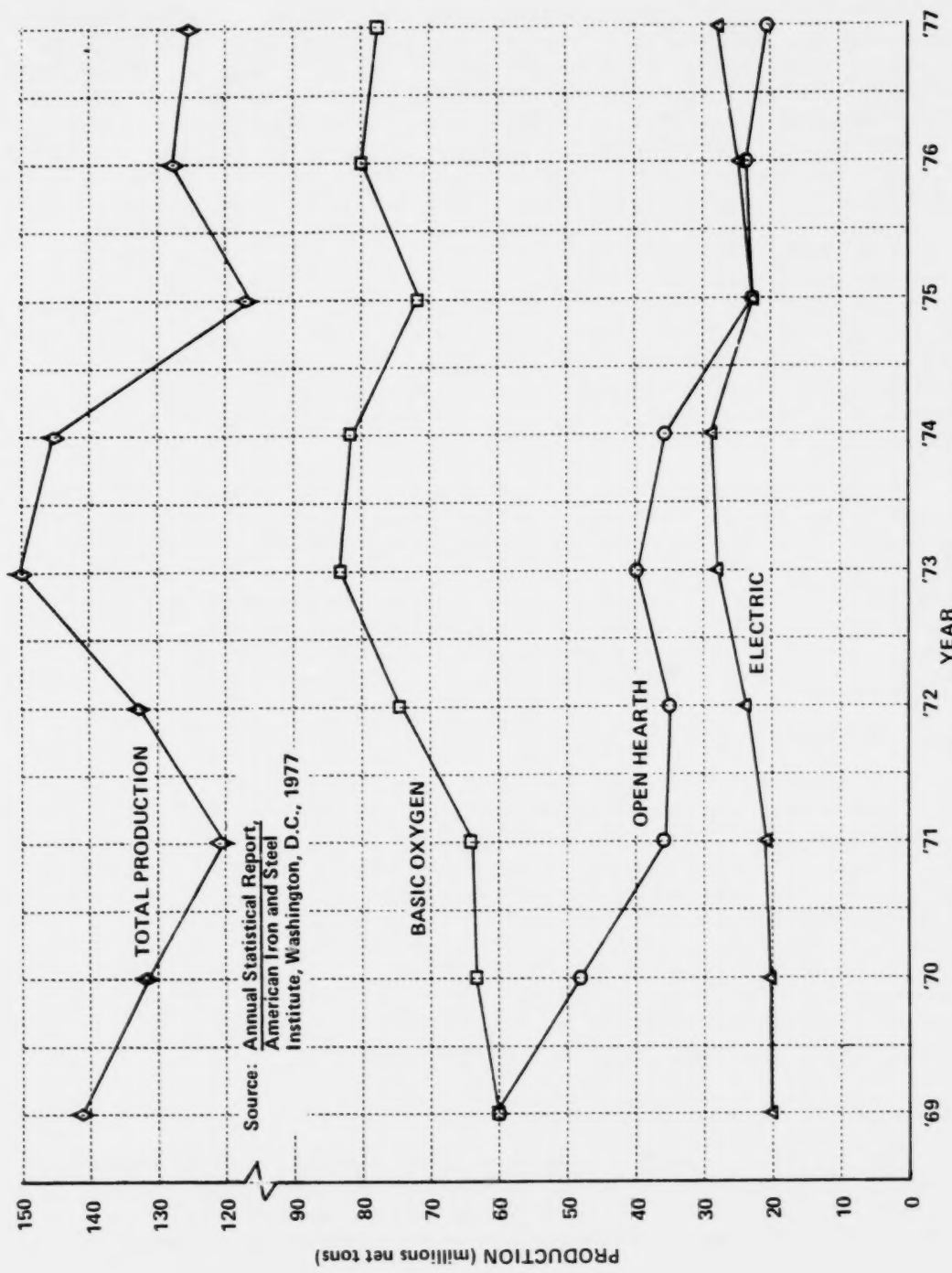


Figure 7-1. U.S. STEEL PRODUCTION BY FURNACE TYPE

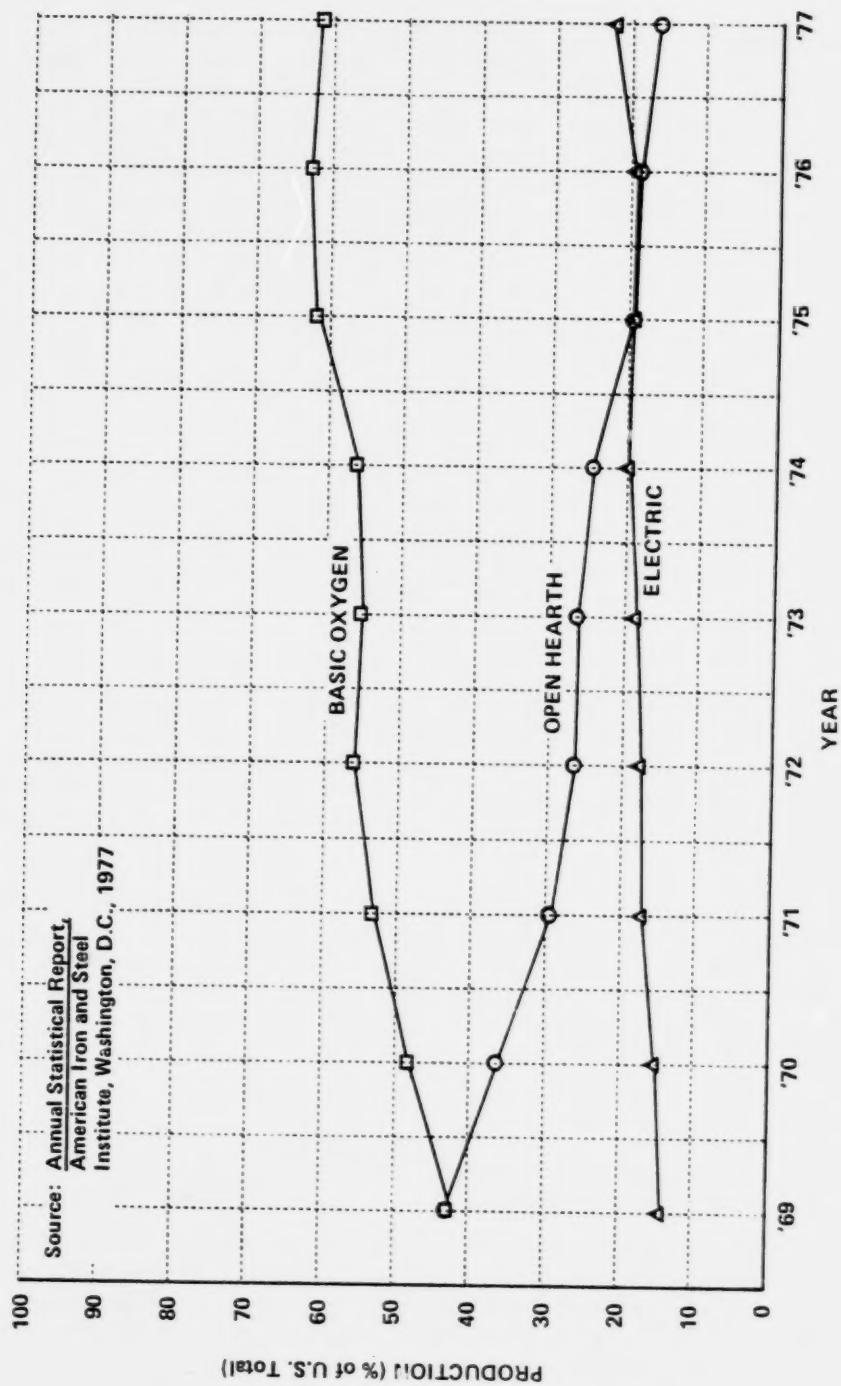


Figure 7-2. U.S. STEEL PRODUCTION BY FURNACE TYPE (% OF TOTAL U.S. PRODUCTION)

construction products--and how these products are distributed. The finished molten steel is transferred to a teeming ladle. The steel is then transferred to ingot molds or to a continuous-caster if one is available. If transferred to ingot molds, the steel is allowed to solidify. The resulting ingots are then removed from the mold and placed in a soaking pit in which precise temperature control is maintained. When the ingots are at a uniform desired temperature throughout, they are transferred to the primary mill where, by repeated rolling operations, they are converted to billets, blooms, or slabs. These intermediate shapes are then further processed by other mills to provide final products of standard shapes and sizes. If the molten steel is transferred from the ladles to a continuous caster, blooms, billets and slabs are cast directly without the need for ingot casting, "soaking," and primary rolling.

It is important to note that in recent years, the annual U.S. shipments of steel products have averaged slightly more than 70 percent of raw steel production. The difference is attributed to the unavoidable losses that occur in transforming the molten steel into finished products. The scrap thus generated is generally returned to the steel-making furnaces for remelting.

Not all steel construction products are made in integrated mills which generally include blast furnaces; steelmaking furnaces; and primary, secondary, and finishing mills. For example, reinforcing bars require only relatively modest facilities and equipment for forming and finishing. Such facilities are frequently found at non-integrated mills. Non-integrated mills, including mini-mills, are major producers of reinforcing bars.

In contrast, sheets, plates, and pipes frequently require extensive milling facilities usually found only at integrated mills. Integrated mills may have various combinations of basic oxygen, open-hearth, and electric-arc furnaces on-site for producing steel. The specific furnace output employed for the production of a particular construction product can vary from day-to-day or week-to-week depending on demand, availability of raw materials, and product specifications.

The amounts of steel from each type of furnace which are allocated to the manufacture of various types of construction products are not recorded. Estimates from a previous EPA study are shown in Table 7-5.

The finished construction products might be shipped directly from the mill to a contractor at a construction site or they might be shipped to a steel service center and sold later to building contractors. Certain types of steel/iron construction products such as doors, door frames, window frames, sheeting and siding, ventilators and duct work, and railings are usually made by fabricators that are not part of the

TABLE 7-5. ESTIMATED PRODUCTION OF STEEL CONSTRUCTION PRODUCTS BY FURNACE TYPES*

	INTEGRATED MILLS		NON-INTEGRATED MILLS
	BOF/Open Hearth	Electric	Electric
Structural	81%	9%	10%
Bars	10	25	65
Sheets, pipe, other	90	10	—

*Source: "Study of the Feasibility of Requiring Secondary Materials in Federal Construction," Resource Planning Associates, Inc., U.S. Environmental Protection Agency (Contract No. 68-01-2272), January 1975.

companies supplying the standard mill-type products. These fabricators purchase finished steel of the sizes and shapes required to manufacture their own line of products. This steel might be purchased from a steel service center or directly from a mill. Because of the multiple routes that the steel can follow from its molten state in the ladle to a specific construction project, as a finished product, it is clear that certification of the recovered material content of the products delivered to their final destination could require a rather involved system of record keeping, at least for some product categories.

Iron and Steel Casting

Iron and steel foundries produce castings for use in a wide variety of applications, including construction-related activities. In iron foundries, the predominant type of furnace for metal melting is the cupola furnace, while in steel foundries, electric-arc furnaces predominate.

The cupola furnace consists of a cylindrical shell of steel lined with fire brick or other suitable refractory material. The shells range from 2 to 9 feet in diameter and have refractory linings 9 to 12 inches thick. To start a heat, a bed of coke is placed at the bottom of the shell and ignited. Air is supplied through tuyeres located along the circumference of the lower part of the shell. After the coke is ignited, alternate layers of metal (pig iron, scrap iron, and/or scrap steel) and coke are placed over the bed. Limestone is added as a flux. The charge usually consists of eight to ten parts by weight of metal to one part of coke. As melting takes place, the charge gradually descends in the shell and additional layers of metal and coke are added as necessary. Molten iron is tapped from the bottom of the furnace through a tap hole. The capacities of cupola

furnaces range from 1 to more than 50 tons per hour.

The electric-arc furnaces used in steel foundries operate on the same principle as those used in steelmaking (see preceding discussion on electric-arc furnaces), but they are generally smaller. Capacities of electric-arc furnaces in steel foundries are usually in the 1 to 25 ton range.

After the iron or steel is melted and brought to specification, it is tapped into a ladle and then poured into a prepared mold, usually formed of sand, where it assumes the shape of the mold and solidifies. After solidification, the casting is removed from the mold and cleaned. Surface imperfections are removed by grinding wheels or torches.

Cast iron soil pipe and cast iron pressure pipe are the two major construction-related products produced in foundries. In modern foundries, cast iron pipe is generally produced by means of centrifugal casting in which a sand-lined or water-cooled metal mold is rotated on a horizontal axis as molten iron is introduced. As the iron solidifies, a pipe having a highly uniform wall thickness is produced. The various associated pipe fittings are generally made by static casting methods.

Annual shipments of iron foundry products averaged 15.8 million tons over the 10-year period from 1968 to 1977⁷. For this same period, annual steel foundry shipments averaged 1.8 million tons. Of the total annual cast iron shipments, approximately 80 percent are gray iron, 14 percent are ductile iron, and the remainder are malleable iron. Accurate information on the percentage of iron and steel foundry products used in construction is not available. However, cast iron pipe is believed to be the largest single category of foundry products used in construction. For the period 1968 to 1977, annual cast iron pipe production averaged 2.58 million tons, with two-thirds as cast iron pressure pipe and one-third as cast iron soil pipe.

UTILIZATION OF RECOVERED MATERIALS

The use of scrap in iron and steel production has been widely practiced since the industry began. Scrap is generally divided into two classes: home scrap (also called revert scrap) and purchased scrap. Home scrap is that scrap generated within a plant, mill, or foundry in the course of making the final products. In steel plants and foundries, this scrap is generally consumed internally, although some might be

7. "Mineral Commodity Profiles, Iron and Steel," MCP-15, Donald H. Desy, Bureau of Mines, U.S. Department of the Interior, July 1978.

sold or shipped to other plants owned by the same company. An example of home scrap in a steel mill are the cropped ends of billets and bloom which are generally returned to the steelmaking furnaces. Home scrap is preferred scrap because its origin is known and it is largely free of contaminants.

Purchased scrap is that scrap purchased from sources outside the mill or plant. In general, purchased scrap consists of prompt industrial scrap and obsolete scrap. Prompt scrap is that scrap generated by steel fabricators in the course of making their products. It consists largely of cuttings, clippings, chips, and turnings. Since prompt scrap is easy to collect and segregate, relatively free of contamination, of known classification, and usually in demand, most prompt industrial scrap is recovered and returned to steelmakers for eventual remelting. Obsolete scrap, also called post-consumer scrap and dormant scrap, consists of all items discarded by the consumer such as appliances, tools, food and beverage containers, automobiles, machinery, components of dismantled buildings and other structures, and obsolete railroad equipment. Not all scrap classified as obsolete is recovered with the same degree of success. Important factors influencing the level of recovery are: the quality of the scrap; its size, concentration and/or location; difficulty of separation from other types of scrap; stability of demand; and current scrap prices.

In the steel industry, the ratio of home scrap to purchased scrap averaged approximately 1.4 to 1 for the 9-year period from 1969 to 1977.

Use in Steelmaking

Annual consumption of scrap in the steel industry for the years 1969 through 1977 is shown in Figure 7-3. The values plotted include both home scrap and purchased scrap. Total scrap consumption generally follows total raw steel production, as is evident from a comparison of Figures 7-1 and 7-3. Both total scrap consumption and total steel production peaked in 1973.

Figure 7-3 also shows annual scrap consumption by furnace type. The decreasing consumption of scrap in open-hearth furnaces is consistent with the decline in steel production in open-hearth furnaces. The figure further suggests that scrap consumption in basic oxygen furnaces closely parallels that in electric-arc furnaces. This observation can be misleading, however, since raw steel production in basic oxygen furnaces is approximately 2.8 times that in electric-arc furnaces.

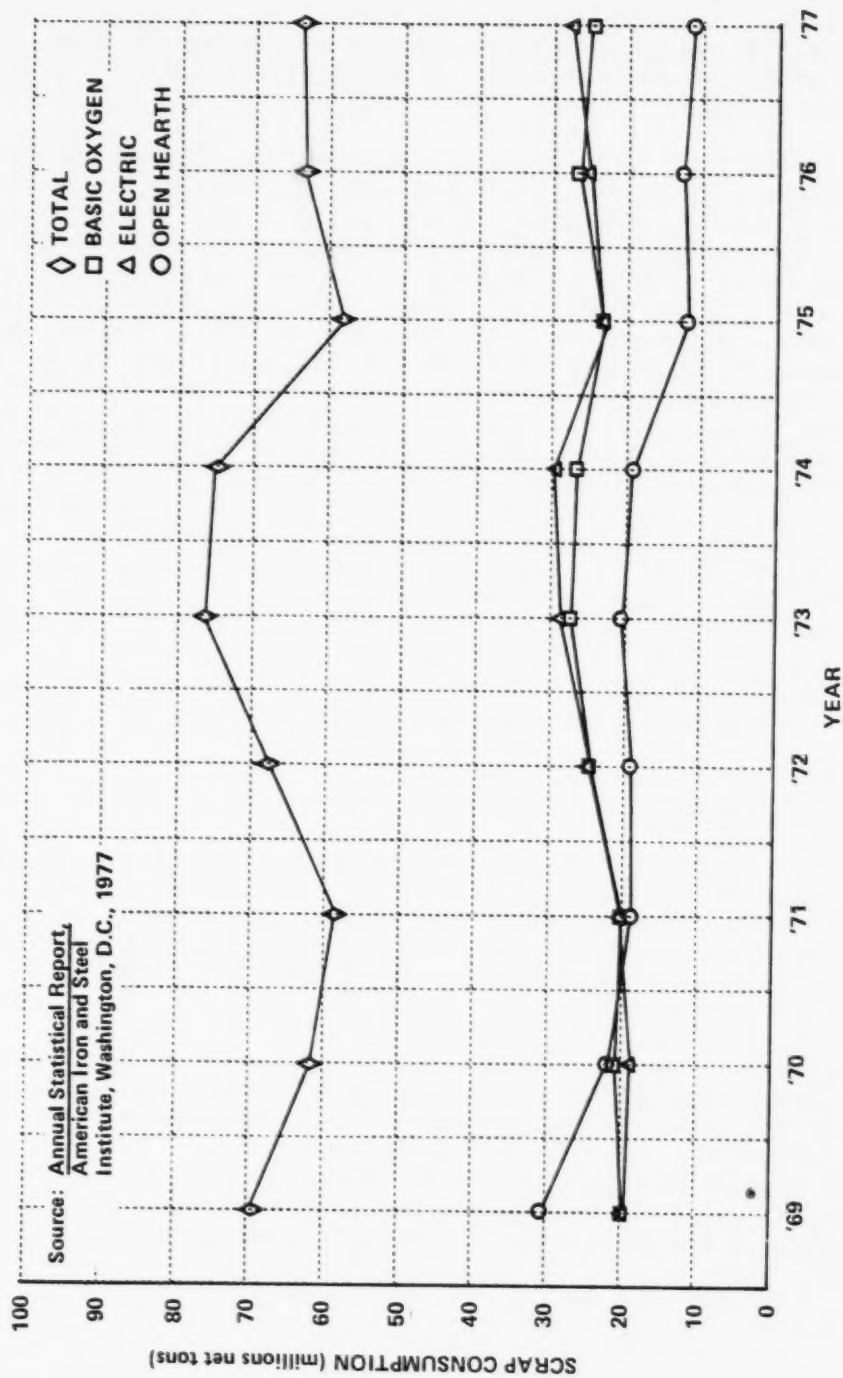


Figure 7-3. SCRAP CONSUMPTION BY FURNACE TYPE (NET TONS)

Figure 7-4 shows annual scrap consumption for each furnace type expressed as a percentage of the total metal charged to the furnace. On this basis, electric furnaces are shown to consume much larger amounts of scrap than either basic oxygen or open-hearth furnaces. A rather striking feature of Figure 7-4 is the constancy of scrap consumption as a fraction of metal charge for both the electric and basic oxygen furnaces. Scrap use in basic oxygen furnaces has been close to the 30 percent limit for cold scrap indicated earlier in the discussion on steelmaking processes. This 30 percent limit on the cold scrap charge is imposed by thermodynamic constraints. Annual scrap consumption in basic oxygen furnaces averaged 28.9 ± 0.7 percent of metal charge for the 9-year period shown in Figure 7-4. For electric furnaces, the average was 97.7 ± 0.8 percent. Most electric-arc steel furnaces are built with the intent of using nearly 100 percent recovered material in the charge.

Scrap charge percentages for open-hearth furnaces show greater variability than for the basic oxygen and electric-arc furnaces. Annual scrap consumption in open-hearth furnaces averaged 45.7 ± 4.0 percent of metal charge for the period from 1969 and 1977. Of particular interest is the peak value of 55.5 percent occurring in 1973, when steel production was at an all-time high. Higher scrap consumption in open-hearth furnaces that year suggests there was a shortage of hot metal (molten pig iron). It is clear that open-hearth furnaces are capable of greater flexibility in the amounts of scrap charged. This might suggest that greater overall scrap consumption in the steel industry could be achieved by increasing scrap use in open-hearth furnaces. This approach does not appear to be practical, however, because of the apparent gradual phasing out of open-hearth operations.

Use in Iron and Steel Foundries

As in steelmaking, the scrap consumed in foundry operations is classified as either home scrap or purchased scrap. In steel foundries, which use electric furnaces for melting, home scrap and purchased scrap combined have accounted for more than 95 percent of the metal charged to the furnaces over the last decade, with 98 percent representing a typical scrap charge. In the case of iron foundries, scrap use in cupola furnaces has increased from approximately 72 percent of the metal charge in 1960 to over 92 percent in 1977, the remainder of the charge being pig iron. In the course of this study, contacts with several large cast iron pipe producers indicated that scrap utilization in cast iron pipe production now approaches 100 percent. For this reason, the development of procurement guidelines for foundry products does not appear to be worthwhile since under recent practice, very little, if any, increase in recovered material use could be realized.

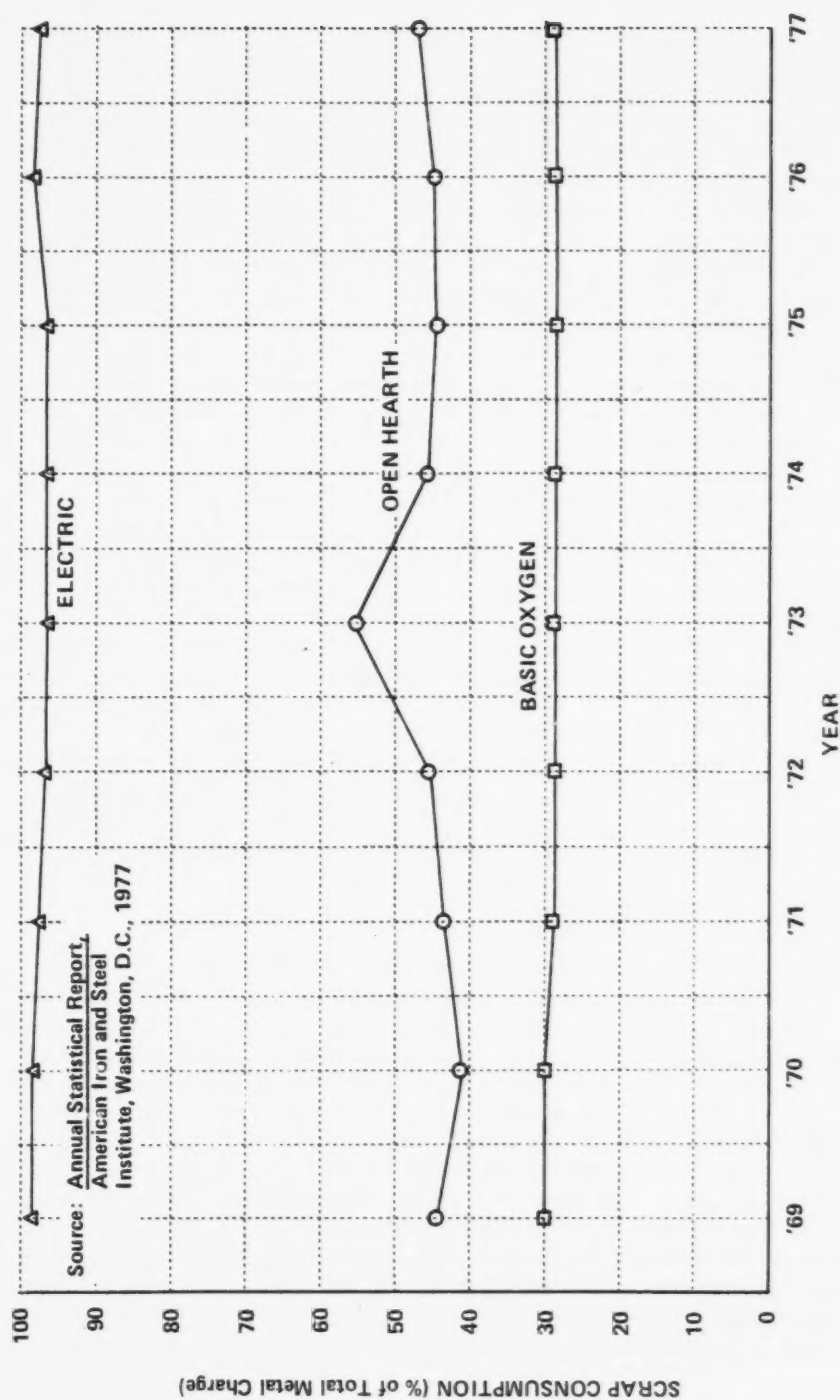


Figure 7-4. SCRAP CONSUMPTION BY FURNACE TYPE (% OF METAL CHARGE)

Sources

Sources of prompt industrial scrap include all types of metal fabricating shops that generate waste material in the process of converting finished steel mill products (e.g., sheets, plates, bars, etc.) into final consumer products (e.g., siding and roofing materials, steel cabinets, doors, window frames, automobile bodies, etc.). Major sources of obsolete scrap include railroads, junked automobiles, farm scrap, public utilities, shipbreaking, and the demolition of structures of various types. Iron and steel scrap recovered from municipal waste represents a small fraction of the total obsolete scrap collected. Purchased scrap consists of approximately equal amounts of prompt industrial scrap and obsolete scrap. In 1977, 92.09 million tons of scrap were consumed by the iron and steel industry, of which 46 percent, or approximately 42.1 million tons, was purchased scrap. Steelmaking accounted for approximately 31.8 million tons of the purchased scrap, and foundries accounted for the remaining 10.3 million tons.

There are a number of ways in which purchased scrap finds its way from the point of generation (prompt industrial scrap) or point of discard (obsolete scrap) to the scrap user. In between, there might be two or more individuals or firms involved, including: collectors, dealers, processors, dealer-processors, processor-brokers, and brokers. Collectors acquire scrap from various individual sources and sell it to dealers or processors. If a dealer has the required facilities, he will process the scrap himself; otherwise, he must sell it to a processor or pay to have it processed. If the processor is also a broker, he will sell the processed scrap directly to the user; otherwise, a broker will buy the scrap from the processor and sell it to the user. In any case, the processor plays a vital role in the scrap cycle. Processing operations include: (1) baling, in which appliances, automobiles, and other scrap forms are squeezed into compact bundles; (2) shredding, in which the scrap is literally ripped into fist-size pieces; and (3) shearing, in which heavy scrap is cut into pieces of desired length.

Quality and Product Performance

In the making of steel, the quality of the scrap introduced with the metallic charge is a matter of great importance. The amount of scrap of any given type that can be added to the melt depends, among other things, on the amounts and types of contaminants it contains, and the grade of steel being produced. Other factors also affect the desirability of scrap, including the size of individual pieces or bundles, and the bulk density. In addition, certain types of scrap cause emission control problems in furnace operations.

The presence of copper, nickel, tin and other elements in the scrap can cause serious problems because they alloy readily with the steel and can impart undesirable properties to it. For example, in construction products, tin in excess of 0.05% can be deleterious in even the lowest grades of material used in noncritical applications. There is the added problem that certain undesirable elements contained in scrap can contaminate not only a given heat, but successive heats as well through the deposition of residue in the furnace lining.

Because of limitations imposed on steelmaking by the quality of the scrap and because of the wide variability in the sources and types of scrap, it is necessary to separate scrap according to grade. Clearly, the grade of the scrap will have a direct bearing on its selling price. While most scrap sold to the steel industry is already separated to some degree, further segregation is often practiced by the user. This is particularly true in the case of electric furnace operations producing a broad range of steel grades involving various alloying materials. Segregation is based on tests performed on the scrap, including chemical and spectrographic analyses.

In steelmaking, each heat of steel is made to exacting specifications which carefully spell out the allowable limits on contaminant levels. These specifications vary with the grade of steel being made, and the grade of steel, in turn, depends on the final product and its intended application. Samples are generally taken of each heat of steel and analyzed to insure that the composition specifications are met. In certain cases, mechanical testing to measure such properties as strength and hardness might also be performed at some stage in the making of the final product. Thus, by carefully controlling the steelmaking process and the amounts and grades of scrap used, the quality and performance of the end products can be maintained within acceptable limits. For practical purposes, products made with recovered materials are indistinguishable from those made with virgin materials, and, in fact, it should be noted that there are no steelmaking facilities operating in the U.S. that use virgin materials only. Since its establishment, the entire industry has been geared to the use of scrap materials.

Factors Influencing Consumption

In considering those factors that influence scrap consumption in the iron and steel industry, it is instructive to examine recent trends in scrap utilization. Figures 7-3 and 7-4, discussed previously, show scrap consumption data for the years 1969 through 1977 by type of steelmaking furnace. Figures 7-1 and 7-2 show raw steel production for the same period. If the total scrap consumed in any given year in steelmaking furnaces (see top curve of Figure 7-3) is expressed as

a percentage of the corresponding amount of total raw steel produced (see top curve of Figure 7-1), we find that annual scrap consumption for the period 1969 to 1977 averaged 49.9 ± 1.4 percent of raw steel production with a low value of 47.1 percent and high value of 51.7 percent. A linear regression analysis of the scrap consumption and raw steel production data indicates a correlation of 0.965. In spite of the fact that the relative amounts of steel made in basic oxygen, open-hearth and electric-arc furnaces have changed drastically in these 9 years, the annual amount of scrap consumed by all steelmaking furnaces has remained at a nearly constant fraction of total raw steel production.

Let us now consider scrap utilization within the entire iron and steel industry, including both steelmaking and foundry operations. A summary of the consumption, production, and purchase of scrap in the industry is given in Table 7-6 for the period 1969 to 1977. Also shown are the annual shipments of all iron and steel products, including steel mill products and foundry products. Of the total scrap consumed by the industry, the production of raw steel accounts for approximately 72 percent on the average. Note that annual figures for total scrap consumption given in Table 7-6 do not necessarily equal the sum of the figures for purchased scrap and home scrap production for the same year, although in most cases, the sum is within two percent of the total scrap figure. The differences are understandable since, at the end of any given year, the amount of scrap in stockpiles might be greater than or less than that at the end of the previous year.

Scrap figures in Table 7-6 are expressed in two ways: by weight in millions of tons and as a percentage of total product shipments for the industry. For the 9-year period covered, annual figures for total scrap consumption averaged 82.9 percent of product shipments with a deviation of ± 2.7 . A linear regression analysis of the data indicated a correlation of 0.953 between product shipments and total scrap consumption. Annual figures for purchased scrap averaged 36.2 ± 3.2 percent, and the figures for home scrap production averaged 46.8 ± 2.3 percent. The correlation between purchased scrap and product shipments was 0.756, while the correlation between home scrap production and product shipments was 0.884. The data for consumed scrap, purchased scrap, and home scrap as a percent of steel mill and foundry shipments are plotted in Figure 7-5. The plotted data show that total scrap consumption as a percentage of total shipments has remained fairly constant. For purchased scrap and home scrap, the data suggest that the ratio of home scrap to purchased scrap might be gradually decreasing. The home-scrap-to-purchased-scrap ratios are given in the last column of Table 7-6. The ratio decreased rather abruptly from 1971 to 1972 and then more or less leveled off, with the exception of 1974, when the ratio dropped to 1.08. The decrease in this ratio is the result of a rather significant increase in the amount of scrap purchased on a percent-of-shipment basis and a somewhat lesser decrease in the generation of home scrap.

TABLE 7-6. CONSUMPTION, PURCHASE, AND PRODUCTION OF SCRAP
IN THE IRON AND STEEL INDUSTRY*

YEAR	TOTAL STEEL MILL AND FOUNDRY SHIPMENTS (million tons)	TOTAL SCRAP CONSUMPTION		PURCHASED SCRAP		PRODUCTION OF HOME SCRAP		RATIO: HOME SCRAP TO PURCHASED SCRAP
		(million tons)	(% of shipments)	(million tons)	(% of shipments)	(million tons)	(% of shipments)	
1977	108.8	92.1	84.7	42.1	38.7	49.5	45.5	1.18
1976	106.2	89.9	84.6	41.4	39.0	50.0	47.1	1.20
1975	95.1	82.3	86.5	36.8	38.7	46.0	48.4	1.25
1974	128.2	105.5	82.3	51.3	40.0	55.3	43.1	1.08
1973	131.4	103.6	78.8	44.7	34.0	57.8	44.0	1.29
1972	109.7	93.4	85.1	41.7	38.0	51.2	46.7	1.23
1971	103.0	82.8	80.4	34.2	33.2	49.2	47.8	1.45
1970	107.3	85.6	79.8	34.1	31.8	52.6	49.0	1.54
1969	112.9	94.8	84.0	36.9	32.7	56.3	49.9	1.53
			Avg. 82.9 ± 2.7		Avg. 36.2 ± 3.2		Avg. 46.8 ± 2.3	

*Source: U.S. Department of Interior, Bureau of Mines — Mineral Commodity Profile (Iron and Steel)

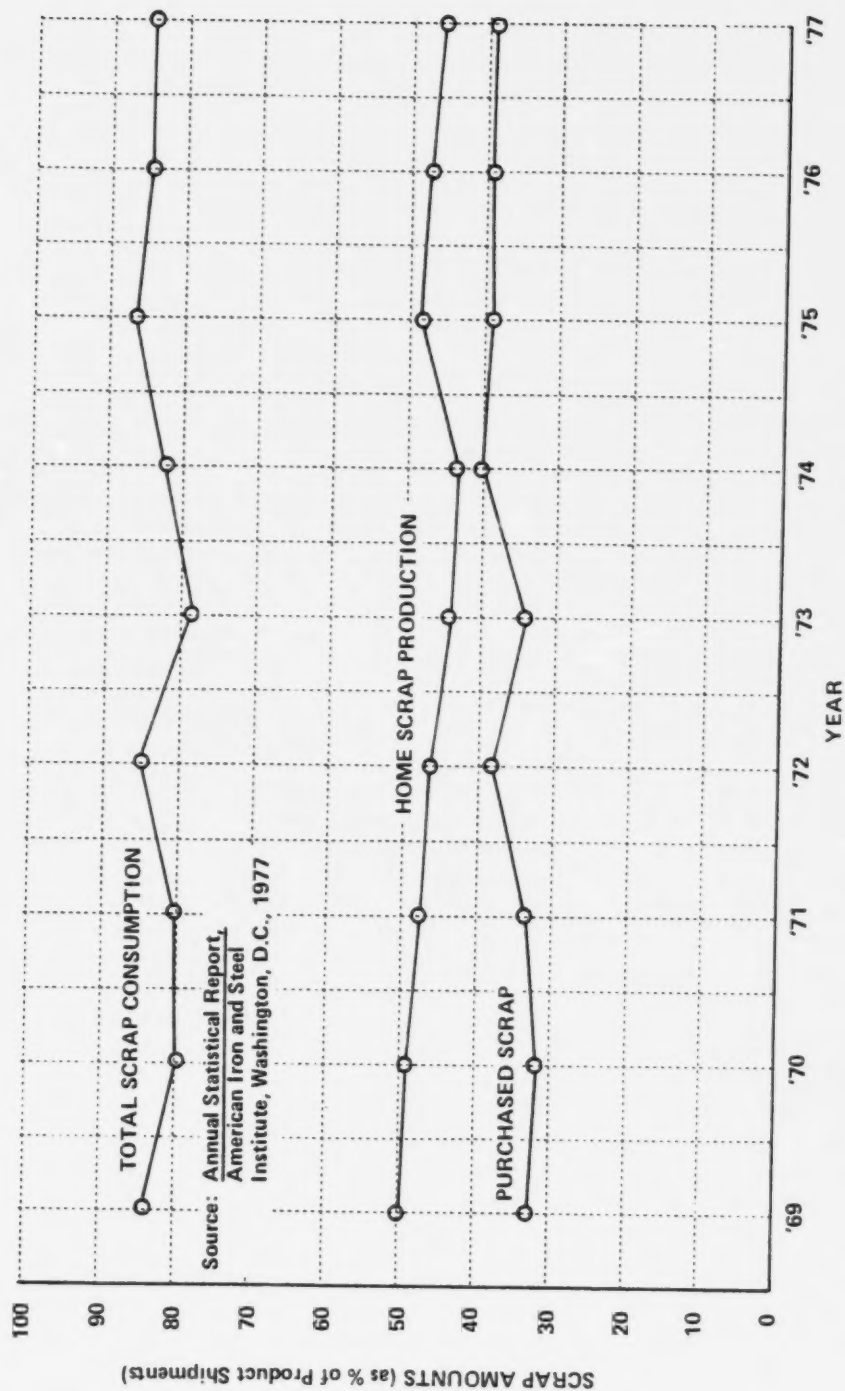


Figure 7-5. SCRAP CONSUMPTION, PRODUCTION AND PURCHASES FOR THE IRON AND STEEL INDUSTRY

Since essentially all home scrap is already consumed in steelmaking and foundry operations, it is the trend in purchased scrap consumption that has greater relevance to one of the major objectives of the Resource Conservation and Recovery Act of 1976; namely, to conserve natural resources. The only way to reduce the amounts of virgin materials required for any given level of iron and steel production is to increase consumption of external (purchased) scrap and to increase the utilization of internally generated wastes that, until recently, were destined for disposal. Examples of the latter include flue dusts and slag which, to some extent, are now being processed for metal recovery.

The data on scrap consumption show that changes in shipments of iron and steel products are generally accompanied by corresponding changes in the amounts of scrap purchased, although the correlation between product shipments and purchased scrap is less than that between product shipments and total scrap consumption. There are many reasons why greater amounts of external scrap are not being used in the production of steel products, based primarily on economic and technical factors.

The data presented in Table 7-6 indicate that in 1977, purchased scrap amounted to 38.7 percent of total iron and steel shipments by weight. Because of the varying composition of purchased scrap, the iron units provided by the scrap probably amounted to only 34 to 35 percent of the iron units represented by product shipments, the bulk of the remainder being provided by iron ore. Clearly, on a continuing long-term basis, external scrap can never provide all of the iron units required to meet steel product demands. Because of population growth, a continuing increase in the amounts of iron and steel products in use, and the unavoidable loss of iron through oxidation, etc., a steady supply of new iron in the form of ore is required. At this point, the percentage of the required iron units that could be supplied by external scrap in the long term is strictly a matter of conjecture. In any case, there would be a wide divergence between "theoretical" projections and "practical" projections. On the theoretical side, there is a large quantity of existing scrap that is potentially recoverable and there is new scrap generated continuously that is not now recovered. On the practical side, there are technical and economic considerations that inhibit the recovery of additional amounts of scrap. It must be remembered that most prompt industrial scrap is already being recovered and presently accounts for roughly half of the purchased scrap. Thus, efforts to increase the supply of purchased scrap must focus on post-consumer scrap. Such scrap is at a disadvantage relative to prompt industrial scrap for several reasons: (1) much of it contains undesirable contaminants; (2) it is more varied in its composition; (3) it is more difficult to recover than prompt scrap; and (4) it generally requires more processing. As a result of these factors, not

only does post-consumer scrap cost more to collect and process than does prompt scrap, but on the average it has less value than prompt scrap in the marketplace. However, since nearly all prompt scrap is being recovered and remelted, post-consumer scrap is really not competing against prompt scrap but rather, against iron ore and the other raw materials required to make iron and steel. It then becomes a question of both convenience and cost on the part of the steelmaker. Because of unwanted contaminants in certain post-consumer scrap, there are advantages to using virgin materials. On the other hand, if post-consumer scrap can be collected, transported, processed, and/or segregated at a cost that makes it cheaper to produce steel by increasing scrap consumption and reducing the dependence on ore, an increase in the demand for post-consumer scrap could be expected.

Two factors sometimes cited as having a direct bearing on the competition between scrap and iron ore as raw materials for steelmaking are the differences in railroad freight rate structures for scrap shipments and iron ore shipments, and the tax benefits available as depletion allowances to integrated steel companies operating their own iron ore mines. The Institute of Scrap Iron and Steel (ISIS) maintains that the present railroad freight rate structure is discriminatory in that the rates for shipping scrap iron and steel average 2.6 times the rates for shipping iron ore.⁸ The Institute of Scrap Iron and Steel recommends that a gradual adjustment in the rate structure be introduced to make the rates more equitable. With respect to depletion allowances, ISIS maintains that the present tax law discriminates against ferrous scrap as a raw material because, in effect, it provides a "subsidy" that prefers virgin materials over scrap. ISIS recommends that the law be modified to provide a tax benefit to consumers of ferrous scrap to offset the advantage provided by depletion allowances.

Annual fluctuations in the demand for iron and steel products and the attendant fluctuations in both raw steel production and purchased scrap demand can also be expected to influence to some degree the competitive status of purchased scrap relative to iron ore. Less volatility in the demand for purchased scrap could encourage the recovery of greater amount of scrap from sources not fully exploited because it might become more attractive economically to invest in the equipment and facilities required to recover such scrap on a more efficient basis. The figures given in Table 7-6 indicate a rather disappointing picture of growth in the domestic iron and steel industry. Total shipments for the 3-year period from 1975 to 1977 were less than the total shipments for 1969 through 1971. Percentage changes in purchased scrap from one

8. "Discriminatory Railroad Freight Rates," Institute of Scrap Iron and Steel, December 1977.

year to the succeeding year averaged more than 11 percent for the period from 1969 to 1977. From 1974 to 1975, a 28.3 percent drop in the demand for purchased scrap was accompanied by a 25.8 percent drop in product shipments. Such fluctuations are not conducive to the development of a stable scrap market and increased investment in scrap recovery facilities.

In efforts to stimulate the utilization of post-consumer scrap in the production of iron and steel products, it is necessary to consider the present supply of available scrap and how the supply is likely to respond to increased demand. A report prepared for the American Iron and Steel Institute (AISI) discusses in detail those factors that affect demand and supply and projects scrap supply and demand for the year 1982.⁹ Data comparing 1973 and 1982 scrap demand are summarized in Table 7-7.

For steel mill and foundry products, the total shipments for 1982 are projected to be 15.2 percent larger than in 1973. At the same time, total scrap requirements will increase by 23.4 percent. The larger rate of growth in scrap demand over shipments is due primarily to a projected increase of 63.9 percent in the amount of raw steel produced in electric furnaces which use nearly 100 percent scrap in the charge, and a somewhat lesser projected increase (32.2%) in the amount of raw steel produced in basic oxygen furnaces which use less than 30 percent scrap in the charge. The increase in the demand for purchased scrap from 1973 to 1982 is projected to be 38.1 percent. The projected increase in demand for purchased scrap is higher than that for total scrap because the production of home scrap, expressed as a percent of product shipments, is expected to decrease, thereby resulting in a disproportionate increase in the demand for purchased scrap. The decrease in the generation factor for home scrap is due to an anticipated increase in the use of continuous casting and to changes in the mix of steel products. The generation factor for prompt industrial scrap is also projected to decrease such that the generation of prompt industrial scrap in 1982 will be only 7.9 percent higher than in 1973. The combination of lower generation factors for both home scrap and prompt scrap, and the higher demand for total scrap expressed as a fraction of product shipments, results in a 75 percent increase in the demand for obsolete scrap for the period from 1973 to 1982.

9. "Purchased Ferrous Scrap - United States Demand and Supply Outlook," William T. Hogan, S.J. and Frank T. Koelble, Industrial Economic Research Institute of Fordham University, June 1977.

TABLE 7-7. SUMMARY OF IRON AND STEEL SCRAP DEMAND
(1973 AND 1982)*

	1973		1982		PERCENT CHANGE IN TONNAGE '73 TO '82
	(million tons)	(as % of shipments)	(million tons)	(as % of shipments)	
A. Steel Mill and Foundry Products					
Shipments	130.1	100.0	151.4	100.0	15.2
Total Scrap Requirement	107.6	82.7	132.8	87.7	23.4
Home Scrap Production	64.0	49.2	72.6	48.0	13.4
Purchased Scrap Demand	43.6	33.5	60.2	39.8	38.1
Prompt Scrap Generation	24.0	18.4	25.9	17.1	7.9
Obsolete Scrap Demand	19.6	15.1	34.3	22.7	75.0
B. All Segments of Iron and Steel Industry					
Total Scrap Requirement	113.6	—	140.0	—	23.2
Home Scrap Production	65.0	—	73.7	—	13.4
Purchased Scrap Demand	48.6	—	66.3	—	36.4
Prompt Scrap Generation	24.0	—	25.9	—	7.9
Obsolete Scrap Demand	24.6	—	40.4	—	64.2
C. Scrap Exports					
Purchased Scrap Exported	11.4	—	15.4	—	35.1
D. Total Domestic and Export Demand					
Total Purchased Scrap Demand**	60.0	—	81.7	—	36.2
E. U.S. Purchased Scrap Supply					
	60.0	—	70.7	—	17.8

*Source: "Purchased Ferrous Scrap -- United States Demand and Supply Outlook," Industrial Economic Research Institute of Fordham University, June 1977

**Total purchased scrap demand is the sum of exports and domestic purchased scrap demand.

Table 7-7 also lists the scrap requirements for all segments of the iron and steel industry which include blast furnace operations and "other," as well as, steel mills and foundries. Since steel mills and foundries dominate the total industry, the relative amounts in all scrap categories for the total industry are close to those for the steel mill and foundry category.

Each year, some fraction of the domestic scrap is exported for use in foreign iron and steelmaking operations. The table shows that the amount of exported scrap will increase by 35.1 percent for the 1973-1982 period. Item D of Table 7-7 shows the total demand for U.S. "purchased scrap" for 1973 and 1982 as the sum of domestic purchased scrap demand and export demand. Item E of the table shows that by 1982, the U.S. supply of purchased scrap will have increased 17.8 percent over the 1973 level. Comparison of Items D and E shows that the U.S. supply of purchased scrap in 1982 will be 11 million tons short of the projected demand of 81.7 million tons.

Of the 70.7 million ton supply of purchased scrap projected for 1982, approximately 42 million tons is obsolete scrap and the remainder is prompt industrial scrap except for a small amount classified as "other". Projections for obsolete scrap supply are more difficult to make than those for the supply of prompt industrial scrap, which is closely related to shipments of steel mill and foundry products and fairly predictable, at least to the extent that shipments are predictable. The Fordham University report⁹ notes that the supply of obsolete scrap is subject to such influences as the useful lives of iron and steel-containing items, their production in past periods, and the extent to which changing usage practice affects their withdrawal from service and their ultimate disposal for recycling. The report goes on to observe that the extent of recycling activity and the associated supply of obsolete scrap usually vary in response to scrap-market conditions as reflected in scrap prices, within limits imposed by the available stock of recyclable discards. However, during periods of peak market demand, the supply of obsolete scrap no longer remains responsive to scrap prices once the stock of recyclable items nears depletion.

In the Fordham University study,⁹ historical data on scrap supply were reviewed and a detailed analysis was made of scrap supply-price data for the high demand period of 1973-1974. According to the report, scrap-price escalation during 1973-1974 reached an all-time high. On the basis of monthly composite averages of the prices of No. 1 heavy

9. "Purchased Ferrous Scrap - United States Demand and Supply Outlook," William T. Hogan, S.J. and Frank T. Koelble, Industrial Economic Research Institute of Fordham University, June 1977.

melting steel at Pittsburgh, Philadelphia, and Chicago, the annual average of monthly scrap prices showed an increase from \$36.63 per ton in 1972 to \$57.67 in 1973 and \$107.83 in 1974. The lowest scrap price of \$46.50 per ton for the years 1973 and 1974 occurred in April 1973. The highest price of \$126.30 per ton occurred in July 1974. In spite of the 87 percent increase in the annual average of monthly scrap prices that occurred between 1973 and 1974, the quantity of No. 1 heavy melting steel supplied increased only about 2 percent from 8,523,900 tons in 1973 to 8,692,984 tons in 1974.

The Fordham study⁹ included regression and correlation analyses of No. 1 heavy melting steel scrap supply and prices for the 1973-1974 period. The effects of time lags of 0, 1, and 2 months between scrap price and quantity supply were evaluated. The correlation coefficients for the cases were calculated to be 0.2380, 0.2972, and 0.2968 for time lags of 0, 1, and 2 months, respectively. Further, the analysis showed that for the case of highest correlation (1 month lag between scrap prices and quantities supplied), the supply elasticity, defined as the percentage change in quantity supplied divided by the percentage change in price, was 0.07, indicating that the monthly quantity of scrap supplied increased only 7.0 percent in response to a 100 percent increase in scrap price. The report attributes the low correlation between scrap supply and price and the highly inelastic behavior of supply to a "virtual maximization" of supply resulting from "input constraints on the availability of ferrous-bearing wastes." It points out that, while at the time (1973-1974), the capacity of the scrap industry could have accommodated an increased level of processing activity, the limited stock of available recyclable material prevented the scrap supply from responding adequately to higher scrap prices.

The conclusion of the Fordham University study⁹ is in apparent contradiction to a study made by Robert R. Nathan Associates under the sponsorship of the Metal Scrap Research and Education Foundation.¹⁰ This study examined the accumulation and availability of iron and steel scrap as of December 31, 1975 and concluded that there were 636 million tons available, enough to supply domestic and export demands at 1975 purchasing levels (46.4 million tons) for the next 14 years without drawing on the millions of tons of scrap that become available each year. At the same time, this study concluded that the scrap industry has a high processing capacity and that the industry could have processed nearly twice the amount of scrap processed in the peak year of 1974,

9. "Purchased Ferrous Scrap - United States Demand and Supply Outlook," William T. Hogan, S.J. and Frank T. Koelble, Industrial Economic Research Institute of Fordham University, June 1977.
10. "The Horn of Plenty Keeps Overflowing," Phoenix Quarterly, Vol. 9, No. 3, Fall 1977, Institute of Scrap Iron and Steel, Inc., Washington, D.C.

a conclusion compatible with the contention of the Fordham study that the scrap processing capacity was not a factor in limiting scrap supply in 1973-1974. The scrap industry expects its processing capacity to increase to between 130 to 140 million tons within the next few years.

The RRNA estimate¹⁰ of the 1975 inventory of obsolete ferrous scrap is based in part on figures developed in an earlier study¹¹ which estimated the 1955 inventory of ferrous scrap to be 537 million tons. The RRNA study¹⁰ first reduced this figure by 13.2 percent to place it on a "potential reserves" basis and then made adjustments for corrosion losses in this inventory both for the period prior to 1955 and for the period from 1956 to 1975. Additions to the inventory for the 1956-1975 period were then estimated and also adjusted for corrosion losses. The adjusted 1955 inventory and the net additions for the 1956-1975 period totaled 636 million tons. In developing the estimates of scrap additions for the 1956-1979 period, the RRNA study¹⁰ examined iron and steel shipments in 15 basic product categories. Estimated amounts of prompt industrial scrap were subtracted from the shipments, and product lifetimes were studied to provide a basis for estimating the rate at which products become obsolete. At the same time, the study recognized that not all obsolete ferrous materials are recovered and recycled. Some are lost to the recovery system because it is not economical to recover and process them. It was estimated that 41 percent of the scrap reserve at the end of 1975 was generated within the last 20 years.

The Fordham University report⁹ also considers the approach of predicting scrap supply by estimating the reservoir of obsolete ferrous materials. However, it concludes, in effect, that the scrap reservoir approach has too many shortcomings and that, frequently, adequate account is not taken of the technical limitations imposed by the chemical and physical characteristics of the scrap which sometimes preclude the recycling of certain types of scrap or make it necessary to use scrap on a highly diluted basis. The Fordham study⁹ chose to project future supplies of obsolete scrap on the basis of the rate of obsolete scrap withdrawal from the total U.S. inventory of iron and

9. "Purchased Ferrous Scrap - United States Demand and Supply Outlook," William T. Hogan, S.J. and Frank T. Koelble, Industrial Economic Research Institute of Fordham University, June 1977.
10. "The Horn of Plenty Keeps Overflowing," Phoenix Quarterly, Vol. 9, No. 3, Fall 1977, Institute of Scrap Iron and Steel, Inc., Washington, D.C.
11. "A Survey and Analysis of the Supply and Availability of Obsolete Iron and Steel Scrap," prepared for U.S. Department of Commerce, Business and Defense Services Administration by Battelle Memorial Institute, January 1957.

steel, which, at year's end in 1974, was an estimated 2.33 billion tons. This figure represents the total amount of iron and steel dispersed throughout the United States in products, structures, discards, and obsolete scrap. The annual scrap withdrawal rate, defined as the amount of obsolete scrap withdrawn from the scrap inventory in a given year expressed as a percentage of the total inventory of iron and steel, was calculated for the 20-year period from 1955 to 1974. The average withdrawal rate for this period was 1.26 percent, with the highest rates of 1.62 and 1.63 percent occurring in 1973 and 1974, respectively. The low of 0.86 percent occurred in 1958. The Fordham study⁹ compares the record high withdrawal rates for the 1973-74 period with five other periods of heavy scrap demand, as follows: World War II (1941-45); Korean War (1950-51); the automobile boom of 1955-56; and two record steel years (1953 and 1969). For these periods, the highest withdrawal rate of 1.58 percent occurred during the 1955-56 automobile boom and the lowest of 1.26 percent occurred both during World War II and the record steel year of 1953. Thus, the withdrawal of obsolete scrap in the 1973-74 period was at a rate higher than during any other period of high scrap demand.

The Fordham Study⁹ projects a total U.S. iron and steel inventory for the year 1982 at 2.64 billion tons, up 13.3 percent from the 1974 level. Applying a scrap withdrawal rate of 1.63 percent to the 1982 iron and steel inventory, the study predicts that the nation's total obsolete scrap supply in 1982 will be 43.0 million tons (including carbon, alloy, and stainless steel grades), or 42.0 million tons excluding alloy and stainless steel grades. As shown in Table 7-7, the 1982 demand for obsolete scrap will be about 55.8 million tons, including 40.4 million tons of domestic demand and 15.4 million tons for exports.

Clearly, there is wide divergence in the conclusions arrived at in the RRNA study¹⁰ and the Fordham study.⁹ The difference appears to be not so much in the amounts of iron and steel in the total U.S. inventory but rather, in the amount of scrap of suitable quality that is truly "available" and the fraction of this scrap that can realistically be expected to reach consumers in periods of high scrap demand. Some of the scrap that is "available" is incapable of being recovered, suitably processed, and sold at prices that make it competitive with virgin materials. As noted previously, one of the difficulties in

9. "Purchased Ferrous Scrap - United States Demand and Supply Outlook," William T. Hogan, S.J. and Frank T. Koelble, Industrial Economic Research Institute of Fordham University, June 1977.

10. "The Horn of Plenty Keeps Overflowing," Phoenix Quarterly, Vol. 9, No. 3, Fall 1977, Institute of Scrap Iron and Steel, Inc., Washington, D.C.

attempting to promote increased use of recovered materials is the variability in steel demand/production which is reflected as fluctuations in the demand for obsolete scrap. A steady demand for scrap might encourage the construction of more facilities and the establishment of more companies for recovering the "available scrap". The Fordham study⁹ shows little correlation between the quantity of scrap supplied and prices paid in the 1973-74 period, and attributes the failure of the supply to respond to increased prices as evidence that the limit of supply had been approached. However, if the demand had persisted for a longer period, it might have induced the scrap industry to invest in facilities and equipment needed to tap additional sources of scrap that heretofore had not been utilized because of cost considerations. In other words, even though scrap prices were high, the scrap industry was either unwilling or unable to respond in the relatively short period of high demand. It is worthy to note that from 1974 to 1975, the consumption of iron and steel scrap dropped 22.0 percent, from 105.5 million tons to 82.3 million tons. It would seem that there is a limit to how much an industry is willing to invest to satisfy relatively short-lived periods of high scrap demand when the demand can decrease so drastically within a year.

In addition to the economic and supply factors discussed above, there are technical factors that influence the degree of scrap utilization. One of these, scrap quality, was discussed previously. Another is the "mix" of steelmaking furnaces within any given company. Electric-arc furnaces can accept a metal charge consisting of nearly 100 percent scrap, while basic oxygen furnaces are limited to about 30 percent scrap. Open-hearth furnaces can, at least theoretically, accept nearly any level of scrap but average scrap consumption is about 45 percent of the metal charge. If a plant has only basic oxygen furnaces, it is limited to scrap consumption approaching 30 percent of the metal charge. Most of this 30 percent is usually made up of home scrap, so there is little demand for large quantities of purchased scrap. In plants having electric-arc furnaces only, the metal input will consist almost entirely of scrap. While a fraction of this will usually consist of home scrap, most of the scrap utilized will be purchased scrap. Since electric furnaces require no hot metal (pig iron), they can be operated independently of a blast furnace. Basic oxygen furnaces, on the other hand, require up to 70 percent molten metal and, therefore, are operated in conjunction with blast furnaces. Although open-hearth furnaces can operate without pig iron, they are nearly always operated where molten pig iron is available.

9. "Purchased Ferrous Scrap - United States Demand and Supply Outlook," William T. Hogan, S.J. and Frank T. Koelble, Industrial Economic Research Institute of Fordham University, June 1977.

Because of the variability in the amounts of scrap that the various types of furnaces can utilize, the demand for purchased scrap at any given plant at any given time will depend on the types of furnace in operation, their production levels, and the grades of steel being produced. Given that open-hearth furnaces are gradually being phased out, there appear to be only two courses available for increasing scrap consumption in steelmaking furnaces to any significant level: (1) increase the percentage of steel made in electric furnaces above the present level of about 24 percent; and (2) increase the amount of scrap that can be accepted by basic oxygen furnaces by heating the scrap before it is charged to the furnace. The first approach is already being implemented to some degree since the percentage of steel made in electric furnaces has increased steadily from level of approximately 14 percent in 1969. The preheating of scrap for consumption in basic oxygen furnaces is not standard practice and is considered by the industry to be economically feasible only under special circumstances, such as a shortage of hot metal.

PROCUREMENT GUIDELINES

Introduction

In considering possible government procurement guidelines for iron and steel construction products containing recovered material, it is important to identify those materials that "qualify" as recovered materials within the context of the Resource Conservation and Recovery Act of 1976 (RCRA). Section 1004 of the Act defines "recovered material" as "...material which has been collected or recovered from solid waste." In the Scope of Work for the present study, the Environmental Protection Agency uses the following definition: "...'recovered material' is any material which, after conversion into a finished product and utilization by a fabricator or final consumer, is collected or recovered." The previous sections mentioned the recycling of scrap and also certain types of steel mill waste such as furnace flue dust, slags, and sludges, although the major emphasis has been on scrap. Within the scrap category, three main classes of scrap were identified: home scrap; prompt industrial scrap; and obsolete scrap. It is clear that obsolete scrap and prompt scrap fall within the definition of recovered material pertinent to this study since both classes of scrap are recovered "...after conversion into a finished product and utilization by a fabricator or final consumer,...." The situation for home scrap is different since home scrap is material that never reached the finished product stage. Because of the desirability of home scrap and the fact that it is, almost without exception, completely recovered and recycled, it is not clear that home scrap can be considered as ever having been "...recovered from solid waste." Nevertheless, the American Iron and Steel Institute, speaking for the

steel industry, believes that home scrap does qualify as recovered material under the RCRA.

With respect to flue dusts, slags, and sludges, which are being used in increasing amounts as sinter materials for pig iron production in blast furnaces, there appears to be little doubt that they qualify as "recovered materials". In the past, these materials have, for the most part, been treated as wastes and their recovery, if practiced at all, was limited.

Candidate Guidelines

Candidate procurement guidelines for iron and steel construction products can be divided into three main categories as follows:

1. Specify minimum recovered material content on a per-shipment basis, depending on the type of furnace used to produce the steel.
2. Specify minimum recovered material content on a per-shipment basis, irrespective of type of furnace used to produce the steel.
3. For each manufacturer, specify minimum level for recovered material use for each specific facility in which construction products are produced.

Guideline Category 1

Under guidelines in this category, three different minimum levels of recovered material content would be specified for all types of steel products: one for each of the three types of steelmaking furnaces. For example, in the purchase of structural steel, the procuring agent might require suppliers to certify the type of furnace in which the steel was produced and the percent of recovered material contained in the shipment. To be acceptable, a shipment would be required to contain a minimum of, say, 29.5 percent recovered material if the steel is made in a basic oxygen furnace, 98 percent if made in an electric-arc furnace, and 47 percent if made in an open-hearth furnace. These particular percentages are slightly higher than the average scrap consumption figures for the last ten years. This particular approach has the advantage that it would not eliminate competitors not having the type of facilities required to meet an arbitrarily set minimum recovered material level. For example, if a minimum recovered material level of 50 percent were specified without regard to the type of furnace in which the steel is made, all competitors operating basic oxygen furnaces would be eliminated from consideration.

On the negative side, it is doubtful that this approach would result in significant increases in scrap consumption. Most facilities are probably already operating near the average scrap percentages shown in Figure 7-3 for each furnace type which, with the exception of open-hearth furnaces, are within 2 to 3 percent of the technical limit under normal furnace operating conditions. Specifically, scrap use in basic oxygen furnaces for the 1969-77 period averaged 28.9 percent of the metal charge, just 1.1 percent below the limit of 30 percent. Scrap use in electric furnaces averaged 97.7 percent for the same period, or about 2.3 percent below the theoretical limit of 100 percent. For open-hearth furnaces, scrap input averaged 45.7 percent, or 9.8 percent below the highest annual level of 55.5 percent in 1973. Even if a purchase order were to specify the maximum limits for recovered material content in electric and basic oxygen furnaces and the 55 percent value for open-hearth furnaces, the overall impact on scrap consumption would be small. If a producer were operating below the maximum scrap levels, he would have to increase scrap input only for those heats needed to produce the steel for specific government orders. Assuming that the producer is already operating at the average scrap level in a basic oxygen furnace, the scrap input would increase $(1.1/28.9) \times 100 = 3.8$ percent above the average level. For an electric furnace, the scrap input would increase $(2.3/97.7) \times 100 = 2.4$ percent, and for an open-hearth furnace it would increase $(9.8/45.7) \times 100 = 21.4$ percent.

For the purpose of estimating the overall impact on scrap consumption that a procurement guideline in this category might have, let us assume annual purchases of steel construction products for public construction at a level typical of recent years. Table 7-8 lists purchased amounts in the five major product categories. For each product category, the total purchased amount is apportioned according to the type of furnace in which the steel was made. This apportionment is based on the estimates given in Table 7-5 and on the relative amounts of steel produced in basic oxygen and open-hearth furnaces. For each product category, an ingot-to-shipment yield is indicated.⁹ Using these yield percentages, an estimate is given by furnace type of the total raw steel required to produce the final products. Estimates of scrap consumption (with no guideline) were made by multiplying the total 1977 scrap consumption figures for each furnace type by the ratio of the raw steel level shown in the table to the total amount of steel produced in each respective furnace. Scrap consumption levels (assuming a guideline in effect) were estimated by increasing

9. "Purchased Ferrous Scrap - United States Demand and Supply Outlook," William T. Hogan, S.J. and Frank T. Koelble, Industrial Economic Research Institute of Fordham University, June 1977.

TABLE 7-8. ESTIMATED INCREASE IN THE CONSUMPTION OF IRON AND STEEL SCRAP
WITH IMPLEMENTATION OF CATEGORY 1 GUIDELINE

PRODUCT CATEGORY	ASSUMED INGOT-TO- SHIPMENT YIELD (%)	ANNUAL PURCHASES* (1000 tons)	ESTIMATED QUANTITIES BY FURNACE TYPE (1000 tons)		
			Basic Oxygen	Open Hearth	Electric Arc
Reinforcing Bars	76.5	2,832	224	59	2,549
Piling	78.0	250	179	46	25
Plates and Structural Shapes	64-78.0	7,300	4,694	1,219	1,387
Fabricated Steel Products	70.5	1,850	1,190	309	351
Galvanized Sheets	70.5	2,450	1,752	453	245
		14,682	8,039	2,086	4,557
Raw Steel Required (1000 tons)			11,307	2,934	6,163
Estimated Scrap Consumption** No Guideline (1000 tons)			3,664	1,608	6,150
Scrap Consumption *** With Guideline (1000 tons)			3,803	1,952	6,298
Increase in Scrap Consumption (1000 tons)			139	344	148
					Total Increase 631

* Typical quantities purchased for public construction projects in recent years

** Assuming scrap inputs at average consumption levels

*** Assuming scrap inputs are at maximum levels: BOF - 30%; Open Hearth - 55.5%; Electric Arc - 100%

the scrap consumption for each furnace type by the percentage given previously as follows: Basic oxygen - 3.8 percent, open hearth - 21.4 percent, and electric-arc - 2.4 percent. The last line of Table 7-8 gives the estimates of the maximum increases in the amounts of scrap that would be consumed in each type of furnace if a procurement guideline based on setting minimum levels of scrap by furnace type were adopted. It is significant to note that open-hearth furnaces account for 54.5 percent of the total increase of 631,000 tons. As open hearth furnaces are phased out, most of the production capacity will probably be replaced by basic oxygen furnaces because most of the steel production shown for open hearth furnaces requires milling facilities more commonly associated with basic oxygen furnaces. As a result, the total increase in scrap consumption would be less than that shown in Table 7-8. The value of 631,000 tons is approximately 1 percent of the total amount of scrap consumed annually in steelmaking furnaces.

For any given level of product shipments, the guideline would have little, if any effect on the amount of home scrap generated. Therefore, the 631,000 tons estimated above would have to be purchased scrap. This amount represents approximately 2.5 to 3.0 percent of the annual purchases of scrap for use in steelmaking. For this guideline approach, little would be gained by specifying a minimum percentage of purchased scrap rather than a minimum percentage of total scrap because any home scrap displaced to satisfy a specific order would probably be consumed in later heats with a corresponding temporary decrease in purchased scrap use.

In estimating the impact of a procurement guideline based on specification of a minimum recovered material content by type of furnace, it was assumed that the maximum scrap charge for basic oxygen furnaces is 30 percent. This limit is imposed by heat balance requirements. The molten pig iron constituting the bulk of the metal charge is capable of melting only a certain amount of cold scrap before its temperature drops to an unacceptably low level. However, if the scrap is heated prior to charging it to the furnace, or if the molten pig iron is superheated, a larger fraction of scrap can be accommodated. It appears that preheating the scrap can increase the limit on scrap charge from 30 percent to perhaps 40 percent. If the guideline were to specify a minimum recovered material content of perhaps 37 percent for construction products made from steel produced in basic oxygen furnaces, scrap consumption would increase by $(37.0 - 28.9)/28.9 = 28.0$ percent rather than the 3.8 percent stated previously for a 30 percent minimum level. Accordingly, the amount of scrap consumed in basic oxygen furnaces in the production of steel for use in construction products required for public construction would increase by 1,026,000 tons instead of the 139,000 tons shown in Table 7-8.

Preheating scrap requires the installation of a preheat facility that would use either oil or gas as fuel. Since the President's National Energy Plan has stressed increased use of coal and a diminishing reliance on gas and oil, it is necessary to consider how the use of preheated scrap would affect overall energy requirements for steel-making in basic oxygen furnaces. Estimates have been made using results of a previous study conducted by Calspan Corporation for the U.S. Environmental Protection Agency that compared the environmental impacts of producing steel using virgin materials and recycled materials.¹² For the purposes of the present discussion, it is assumed that scrap has zero energy value at the point of discard. The justification for this assumption is that only two alternatives are considered: (1) allowing the scrap to remain in the waste stream, forever unrecovered; or (2) recovering it and using it as a partial replacement for pig iron in steelmaking.

The energy analysis that follows is based on the production of one ton of ingot steel in a basic oxygen furnace under two different sets of conditions: Case A - a metal charge consisting of 30 percent cold home scrap and 70 percent molten pig iron; and Case B - a metal charge consisting of 30 percent preheated home scrap, 10 percent preheated automotive scrap, and 60 percent molten pig iron. In both cases, the needed iron is supplied by a blast furnace. The analysis considers the total energy and material requirements of the blast furnace and the basic oxygen furnace, as well as the following: the energy required for mining and transporting the required iron ore, coal, and limestone; the energy required for processing and transporting the automobile scrap; and the energy value of gas recovered from the coke oven/blast furnace operations. Shown in the left-hand column of Table 7-9 are the individual operations, facilities, and/or materials considered. Coal mining and coking are included in the blast furnace category. The first column appearing under Case A or Case B shows the amounts of each material required to produce 1 ton of ingot steel. The remaining columns indicate the amounts of energy of each type (coal, petroleum, gas, and electricity) required and the total energy. Summations for the individual columns are given in the bottom line of the table. The electrical energy requirements are stated in terms of thermal energy requirements at the generating source and assume an overall generation-transmission efficiency of 29 percent.

12. "Environmental Impacts of Virgin and Recycled Steel and Aluminum," R.C. Ziegler et al., Calspan Corporation, PB-2534-87/3ST, February 1974.

**TABLE 7-9. COMPARISON OF ENERGY REQUIREMENTS FOR PRODUCING STEEL
IN A BASIC OXYGEN FURNACE USING COLD SCRAP AND PREHEATED
SCRAP**

CASE A							
666 lb HOME SCRAP; 1552 lb PIG IRON							
PROCESS/FACILITY	AMOUNT OF MATERIAL REQUIRED	ENERGY REQUIREMENTS (1000's BTU's)					
		Coal ⁽¹⁾	Petroleum	Gas	Electricity ⁽²⁾	Not Identified ⁽³⁾	Total
Iron Ore Mining	2498 lb	366.8	251.6	180.0	275.0	647.3	1720
Limestone Quarry	699 lb	0.61	12.2	1.51	10.4	48.0	73
Blast Furnace (Pig Iron)	1552 lb	12,123 (18,942)	332.6	533.2	329.4	—	13,318 (20,137)
Basic Oxygen Furnace (Steel Ingot)	2000 lb	0	0	551.1	—	10.4	562
Home Scrap	666 lb	0	0	0	0	0	0
Lime Production	155 lb	170.6	11.7	136.1	25.6	29.3	373
Auto Hulk and Scrap Processing	NA	—	—	—	—	—	—
Oxygen Production	1893 cu. ft.	0	16.3	141.9	433.8	8.82	601
TOTALS	—	12,661 (19,480)	624	1544	1074	744	16,647 (23,466)
CASE B							
666 lb HOME SCRAP; 222 lb OBSOLETE SCRAP; 1330 lb PIG IRON							
Iron Ore Mining	2140 lb	314.3	215.6	154.1	235.8	554.4	1474
Limestone Quarry	616 lb	0.54	10.8	1.3	9.2	42.3	64
Blast Furnace (Pig Iron)	1330 lb	10,389 (16,232)	285.1	456.8	282.2	—	11,413 (17,257)
Basic Oxygen Furnace (Steel Ingot)	2000 lb	0	0	793.2	—	22.0	814
Home Scrap	666 lb	0	0	0	0	0	0
Lime Production	141 lb	155.2	10.8	123.5	23.4	26.6	340
Auto Hulk and Scrap Processing	222 lb	0	41.6	48.7	31.4	65.5	187
Oxygen Production	227 cu. ft.	0	19.6	170.2	520.6	10.3	721
TOTALS	—	10,859 (16,702)	584	1747	1103	721	15,013 (20,857)
DIFFERENCES IN ENERGY REQUIREMENTS		-1802 (-2778)	-40	+203	+29	-23	-1634 (-2609)

(1) Numbers in parenthesis indicate total energy content of coal consumed. The difference between the number in parenthesis and the number above it is the energy credit for gas recovery.

(2) The electricity values take into account an overall efficiency of 29% heat-to-electricity conversion and transmission losses.

(3) The "not identified" energy is largely associated with off-site activities and the mix is expected to be essentially the same for Cases A and B.

For Case A, a total net energy requirement of 16,647 thousand BTU's is indicated, whereas for Case B the total net energy requirement is 15,013 thousand BTU's. Thus, the total energy required to produce 1 ton of steel in a basic oxygen furnace using preheated scrap in amounts up to 40 percent of the charge is 1,634 thousand BTU's less than that required when the charge contains 30 percent cold scrap. The bulk of the energy difference is due to the decrease of 1,802 thousand BTU's in the consumption of coal (coke) in the blast furnace as a result of the partial substitution of preheated scrap for pig iron. A reduction in petroleum consumption of 40 thousand BTU's is also indicated, primarily due to the decreased amounts of ore, limestone, and coal that must be mined and transported under Case B. On the other hand, gas consumption is increased 13 percent, or 203 thousand BTU's.

Whether Case B (preheat) or Case A (no preheat) represents the greater energy benefit depends on the relative value assigned coal, petroleum, and natural gas. The 29 units (thousands of BTU's) of electrical energy can be equated to 4.9 units of natural gas, 4.1 units of petroleum, and 13.0 units of coal, assuming that approximately 45 percent of the electric power generated in the U.S. is based on the burning of coal, 17 percent on the burning of natural gas, and 14 percent on the burning of petroleum (1975 data). The remainder is derived from hydropower and nuclear fuel. Then, the net difference in the energy requirements of Cases A and B amounts to a saving of 1789 energy units of coal and 36 energy units of petroleum for the case of preheating the scrap at the expense of an increase in consumption of 208 energy units of natural gas. Since the current national energy policy encourages the substitution of coal for natural gas and petroleum when possible, arguments opposing scrap preheating because of energy considerations have some validity. However, it can be argued just as convincingly that the total energy saving that could be realized by the use of preheated scrap is sufficient to offset the attendant relatively modest increase in natural gas consumption.

The discussion to this point has assumed that any requirement for minimum recovered material content would be satisfied with scrap. Let us now examine the implications of meeting a minimum recovered material requirement by including materials recovered from flue dusts, sludges, etc., which are sintered and charged to the blast furnace. For electric arc furnace facilities, this will have little importance since electric arc furnaces use little hot metal. However, in the case of basic oxygen furnaces which are charged with 70 percent hot metal or more, sintered materials could bring about a significant relative increase in the recovered material content of the steel. Although detailed published information on the amounts of flue dusts, etc., that are currently being recycled via the blast furnace appears to be lacking,

the American Iron and Steel Institute has indicated that such recovered wastes might account for 10 percent of the iron units charged to blast furnaces in some operations. Thus, if pig iron contains 10 percent recovered material, a charge of 70 percent pig iron and 30 percent cold scrap to a basic oxygen furnace would contain 37 percent recovered material, if all the scrap, regardless of whether it is home scrap or purchased scrap, is counted as recovered material. Now, if a procurement guideline specified minimum recovered material content of, say, 35 percent, a company operating a basic oxygen shop and wishing to supply steel construction products for government-funded projects could qualify in several ways: (1) by using preheated scrap in the steel-making furnace; (2) by using sintered wastes in the blast furnace and using the pig iron as the hot metal charge for the steel furnace (no preheating required in this case); or (3) by a combination of the two.

If home scrap does not qualify as recovered material, then the minimum recovered material content specified in the procurement could be reduced to perhaps 10 percent. This would allow the producer to use the normal amounts of home scrap (which constitute most of the scrap charge in basic oxygen furnaces) but, at the same time, would require him to increase the use of recovered material as preheated scrap and/or as sintered waste. On the other hand, if a level of 35 percent is specified and home scrap is excluded as a recovered material, the scrap fraction (25 to 35 percent) of the recovered material would have to be purchased scrap. Such a large fraction of purchased scrap could be expected to impose stricter control on the quality of the scrap. In any case, the home scrap not consumed in supplying public-funded orders for steel would be consumed at other times, with an attendant decrease in purchased scrap consumption.

Guideline Category 2

In this procurement guideline category, a minimum recovered material would be specified for government-purchased iron and steel construction products without regard to the type of facility in which the products are made, although the level could be different for different types of products. For example, a procurement request for steel reinforcing bars might specify a minimum recovered material content of 95 percent. This high level could be attained only in electric furnaces and open-hearth furnaces, although open-hearth furnaces usually operate at much lower scrap input levels. The effect of such a guideline would be to eliminate from competition those producers who make reinforcing bars in basic oxygen furnaces. Estimates given in Table 7-5 indicate that 90 percent of the reinforcing bars are produced in facilities operating electric furnaces. Of the remaining 10 percent, perhaps 2 percent are made in open-hearth furnaces and 8 percent in basic oxygen furnaces. While, in theory,

it would be possible for the open-hearth operators to make reinforcing bar steel using a minimum scrap input of 95 percent, it is not likely that all would choose to do so. Therefore, a guideline specifying a 95 percent minimum recovered material content for reinforcing bars might eliminate from competition up to 10 percent of the current producers of reinforcing bars. The actual percentage could be less because some of the producers now making bars in basic oxygen furnaces might also operate electric furnaces.

From the standpoint of the effects on competition, a 95 percent minimum recovered material level for reinforcing bars appears to be a reasonable guideline alternative. In terms of the impact on scrap consumption, it is estimated that such a guideline could result in an increase in scrap use of 200,000 tons. This estimate assumes that present scrap practices in electric furnace shops would remain unchanged and that the scrap input would continue to average about 97.7 percent of the metal charge. In 1976, public construction accounted for 2,444,000 tons of reinforcing bars (see "Rebar Usage" Section). Of this amount, assume that 8 percent, or 195,520 tons, was made using steel produced in basic oxygen furnaces and that 2 percent, or 48,880 tons, was made with open-hearth steel. Assume average scrap inputs of 28.9 percent and 45.7 percent for the basic oxygen and open-hearth furnaces, respectively. Considering an ingot-to-shipment yield of 76.5% for reinforcing bars, the raw steel requirements would be 255,600 tons for basic oxygen furnaces and 63,900 tons for open-hearth furnaces. The corresponding total metal charges would be 294,100 tons and 75,000 tons, respectively. Therefore, the scrap consumed in making reinforcing bars is estimated to be $(0.289 \times 294,100) = 85,000$ tons for basic oxygen furnaces and $(0.457 \times 75,000) = 34,300$ tons for open-hearth furnaces. To produce the 244,400 tons of reinforcing bars now produced annually in basic oxygen and open-hearth furnaces, in electric-arc furnaces would require a total metal input of 362,400 tons with a corresponding scrap input of $(0.977 \times 362,400) = 318,900$ tons. Therefore, the increase in total scrap consumption by shifting production from basic oxygen and open-hearth furnaces to electric-arc furnaces would be 199,600 tons. This figure is approximately 0.9 percent of the total amount of purchased scrap consumed in steelmaking. This particular guideline alternative has the advantage that it would be sufficient to have the producer certify that the shipment was made in an electric furnace because the scrap input would generally be within a few percent of the 97.7 percent assumed in the calculation.

For steel construction products other than reinforcing bars, requiring recovered material levels greater than 30 to 40 percent would severely affect competition since it is estimated that well over 60 percent of the steel used in these products (structural, sheets, pipe, and other products) is currently made in basic oxygen furnaces.

Table 7-5 shows that 81 percent of the structural steel shapes fabricated from steel are made in either basic oxygen or open-hearth furnaces, as are 90 percent of the sheets, pipe, and other products. Assuming that about four times as much steel is produced in basic oxygen furnaces as in open-hearth furnaces, it is estimated that about 65 percent of the structural shapes and 72 percent of sheets, pipe, and other products contain steel made in basic oxygen furnaces. Specifying a minimum recovered material level of 40 percent or more would certainly eliminate all producers who must rely on basic oxygen furnaces. At levels in the 30 to 40 percent range, operators of basic oxygen furnaces might meet the requirement by using preheated scrap and/or sintered wastes as discussed previously. As shown below, setting the minimum level at 30 percent would have a relatively small effect on scrap consumption since, as already noted, scrap consumption in basic oxygen furnaces has been averaging 28.9 percent.

In recent years, annual purchases of steel construction products for use in public construction in the structural, sheets, pipe, and "other" category (excluding cast iron pipe) have averaged approximately 10 million tons. It is estimated that about 7 million tons of these products were made with steel produced in basic oxygen furnaces. Assuming that the 7 million tons of finished product represents a total metal charge to the furnaces of about 11.5 million tons, taking into account ingot-to-shipment yields (71%) and ingot losses (86%), the total scrap consumption would average about $(0.289 \times 11.5 \times 10^6) = 3.32$ million tons. Setting a minimum recovered material input of 30.0 percent would increase scrap consumption by $(0.300 - 0.289) \times 11.5 \times 10^6 = 126,500$ tons, which corresponds to approximately 0.6 percent of the annual demand for purchased scrap.

Both this guideline category and the previous one would require the supplier of the steel products to certify the percent recovered material contained therein or used in their production. Regardless of the number of levels involved between the making of the steel in the furnaces and the final delivery of the products to the construction site, it would be necessary for the steelmaker initially to certify the recovered material content of the raw steel ingots. This information would have to follow along through each step of the manufacture, sale, transfer, storage, transport, and delivery of the products. Given that the recovered material content of the raw steel is known, there should be no insurmountable problems in making this information available at all levels. However, the American Iron and Steel Institute believes that certification of the actual recovered material content of a steel shipment can only be made for steelmaking operations in which no hot metal (pig iron) is used. The reason for this is that the hot metal from the blast furnace usually contains some amount of recovered material (slags, flue dust, etc.), and it is impractical to obtain an average value for recovered material content in a time frame

of less than one month.¹³ In fact, AISI believes a three-month averaging period would be more meaningful.

Guideline Category 3

Under this category, any company wishing to sell steel construction products for use in public-funded construction projects would be required to maintain records of recovered material use in those steel-making shops that produce steel for use in public construction projects and to report this information on a quarterly basis. In addition, the company would have to report the total amounts of metal charged to the furnaces. If confidentiality of production data prohibits reporting actual metal amounts charged, the level of recovered material use for the quarter could be reported as a percentage of total metal charged.

A specific guideline might specify that, for steel construction products made in basic oxygen furnaces, the recovered material use for the most recent quarter must be no less than 30 percent of the metal charged to the furnaces. This approach is similar to those discussed under guideline Category 1, but it does not require certification of recovered material content on a per-shipment basis. Minimum levels could be specified for open-hearth and electric-arc furnaces as well. As long as companies responding meet the minimum level requirements, they would all be equally competitive, regardless of the type of furnace used in producing the steel.

Alternatively, the guideline might not specify any minimum levels for recovered material content but use the quarterly figures reported by the companies as a partial basis for selecting the supplier. A simple procedure could be devised for selecting the supplier that would take into account cost as well as recovered material content. For example, suppose a figure of merit F is computed for each bidder such that

$$F = (W_R \times R) - (W_P \times P)$$

where R is the recovered material content expressed as the percent deviation from the average of the recovered material use reported by all bidders, and P is the price expressed as the percent deviation from the average of the prices quoted by all bidders. Both R and P could have positive and negative values, depending on whether the recovered material and price values are above or below the averages. The factors W_R and W_P are weighting factors (< 1) to allow a relative

13. Personal communication. S. G. Fletcher, American Iron and Steel Institute, to R.C. Ziegler, Calspan Corporation, 4 December 1978.

importance to be assigned to recovered material content and price. The supplier having the highest figure of merit would be the successful bidder.

This guideline category has a greater potential for causing significant increases in recovered material use than those discussed under Categories 1 and 2 because it could require companies to operate facilities at the higher recovered material levels for all types of steel products for extended periods. They could not simply increase scrap use, for example, to fill a specific order in response to a purchase request. While it is difficult to predict how much more scrap and other recovered material might be consumed if such a guideline were in effect, it is possible to calculate an upper limit for a given stated level of recovered material content. Suppose a minimum level of 30 percent was specified for basic oxygen furnaces and that the guideline had the effect of causing steelmakers to increase recovered material use in all basic oxygen furnaces to 30 percent, up from the 28.9 percent average. At an annual raw steel output of 80 million tons, basic oxygen furnaces consume about 26 million tons of scrap on the average. At the 30 percent level, scrap consumption in basic oxygen furnaces would increase by about 990,000 tons. If, in addition, all electric-arc furnaces increased scrap use to 100 percent, annual scrap consumption would increase by another 700,000 tons. Setting a level greater than 30 percent minimum recovered material content for basic oxygen furnaces could potentially cause the increase in the utilization of recovered materials to exceed the 990,000 tons. However, the 990,000 ton figure assumes that all basic oxygen furnaces would operate at the 30 percent level, the process limit. If the level is set higher than 30 percent, additional facilities would be required, and it is unlikely that companies would install facilities to allow all basic oxygen furnaces to operate at recovered material levels higher than 30 percent. It is more likely the case that each company would install only those facilities required to fill anticipated orders for public construction projects.

Guideline Discussion

Of the three guideline categories discussed above, the latter (certification by facility) appears to have the greatest merit from the point of view of both the ease of certification and the potential increase in the utilization of scrap and other recovered materials that could be realized. The initial phase in the implementation of the guideline might simply require steel companies to report the average levels of recovered material use for quarterly periods without setting a minimum level. Later, after sufficient data had been accumulated, specific minimum levels could be set. In the case of basic oxygen furnaces, the reporting of recovered material utilization would include both direct scrap inputs as well as indirect inputs of recovered materials through the use of pig iron produced in part with sintered wastes.

Section 8
ALUMINUM CONSTRUCTION PRODUCTS

INTRODUCTION

Aluminum construction products are grouped into five major categories as follows: windows, doors, and screens; awnings and canopies; residential siding; mobile homes; and bridges, streets, and highways. No specific information is compiled, either by government agencies or industry associations, regarding the application of aluminum products in federal government or government supported construction programs. Data series are maintained, however, documenting aluminum production, allocation of aluminum to the various market sectors (i.e., construction, transportation, machinery, etc.), and selected construction uses of aluminum. The combining and analysis of such data allow a gross approximation of the quantity of aluminum employed in federal government and government supported construction programs.

U.S. ALUMINUM NEW SUPPLY

U.S. new supply of aluminum consisting of primary production and secondary recovery is shown in Table 8-1 for the years 1972 through 1977. Production dropped sharply in 1975 and subsequently rose again to the point where 1977 production was approximately equal to the record production achieved in 1974.

TABLE 8-1. U.S. ALUMINUM NEW SUPPLY (1,000 SHORT TONS)*

	1972	1973	1974	1975	1976	1977
Primary Production	4,122	4,529	4,903	3,879	4,251	4,539
Secondary Recovery**	1,126	1,235	1,282	1,239	1,471	1,591
Total	5,248	5,764	6,185	5,118	5,722	6,130

*Source: "Aluminum," Mineral Commodity Profiles, MCP-14, Bureau of Mines, U.S. Department of the Interior, May 1978

"Aluminum Industry in November 1978," Mineral Industry Surveys, Bureau of Mines, U.S. Department of the Interior

"Aluminum," Preprints from the 1975 and 1976 Bureau of Mines Minerals Yearbooks, U.S. Department of the Interior

"Aluminum Statistical Review 1977," the Aluminum Association, Inc.

**Metallic recovery from purchased, tolled or imported scrap. Expanded for full coverage of industry.

Secondary recovery, as a percentage of total production, increased gradually as noted below.

<u>Year</u>	<u>% Secondary Recovery of Total Production</u>
1972	21.5
1973	21.4
1974	20.7
1975	24.2
1976	25.7
1977	26.0

U.S. ALUMINUM DEMAND

The U.S. demand pattern for aluminum for the corresponding time frame is presented in Table 8-2. Average construction use of aluminum accounted for 23% of total demand over this 6-year time period, with relatively small year-to-year fluctuations. The annual use of aluminum for construction ranged between 21 percent and 26 percent.

TABLE 8-2. ALUMINUM: U.S. DEMAND PATTERN (1,000 SHORT TONS)*

	1972	1973	1974	1975	1976	1977
Metal:						
Construction	1,453	1,554	1,330	964	1,279	1,339
Transportation	1,012	1,215	1,053	754	902	945
Electrical	698	804	793	524	594	622
Cans and Containers	536	890	982	858	1,085	1,136
Appliances and Equipment	511	579	499	320	468	490
Machinery	341	409	450	277	417	437
Other	375	374	321	227	373	391
Subtotal	4,926	5,825	5,428	3,904	5,118	5,360
Nonmetal	614	724	773	590	639	670
Grand Total	5,540	6,549	6,201	4,494	5,757	6,030

*Source: "Aluminum," Mineral Commodity Profiles, MCP-14, Bureau of Mines, U.S. Department of the Interior, May 1978.

Major construction applications of aluminum products are shown in Table 8-3. The tonnages represent gross estimates. Nevertheless, they provide an indication of the relative magnitudes of aluminum usage in various construction material sectors.

**TABLE 8-3. ESTIMATED CONSTRUCTION USE OF ALUMINUM
(1,000 SHORT TONS)***

	1972	1973	1974	1975	1976	1977
Windows, Doors, and Screens	413	429	354	296	382	418
Awnings and Canopies	79	95	64	40	60	64
Residential Siding	217	245	225	169	227	221
Mobile Homes	201	195	118	85	118	121
Bridge, Street, and Highway	71	75	76	46	55	55
Other	472	515	493	328	437	460
Total	1,453	1,554	1,330	964	1,279	1,339

Note: The selected markets represent either those in which the Aluminum Association has marketing programs, or which are important aluminum market categories. Tonnages listed under "Other" may include additional shipments to the specified markets as well as shipments to other construction markets.

*Source: "Aluminum," Mineral Commodity Profiles, MCP-14, Bureau of Mines, U.S. Department of the Interior, May 1978

"Aluminum Statistical Review 1977," The Aluminum Association, Inc.

USE OF ALUMINUM IN GOVERNMENT CONSTRUCTION

The relationships between private and public construction programs were discussed earlier in Section 6. The relative values of private and public construction were shown to be as follows:

	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>1977</u>
Total Construction					
% Private	76	72	70	74	78
% Public	24	28	30	26	22
% Federally Owned	4	4	5	4	4
% State and Locally Owned	20	24	25	22	18

Application of these percentages to the construction aluminum tonnages shown in Table 8-2 yields the following estimates of aluminum use in public construction programs. Tonnages are expressed in 1,000's of short tons.

	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>1977</u>
Federally Owned Construction	62	53	48	51	54
State and Locally Owned Construction*	311	319	241	281	241
Total Public Construction	373	372	289	332	295

*Includes federal government additions to state and locally owned construction programs

Federally owned construction programs apparently utilize only relatively small quantities of aluminum construction materials.

The estimated usage of aluminum in public construction programs is compared with domestic primary production, secondary recovery, and total production of aluminum in Table 8-4. In general, the use of aluminum in public construction programs shows a downward trend relative to aluminum production over the time period considered.

Measured by any aluminum production standard--primary, secondary recovery, or total production--federally owned construction programs have consumed only a very small amount of U.S. aluminum production.

The estimated tonnage of aluminum construction materials employed in federally owned construction programs represented 5 percent or less of secondary recovery in the 5-year period. The percentage of aluminum construction products utilized in all public construction programs in 1977 had declined to less than 20 percent of secondary recovery.

UTILIZATION OF RECOVERED METALS

Aluminum end products are classified into two main groups: (a) wrought products such as sheet, plate, rolled and continuous cast rod and bars, wire, extrusions, and forging, and (b) castings, including sand, permanent mold and die castings. In general, wrought products require lower levels of impurities than cast products because common alloying agents such as copper and silicon reduce the ductility of aluminum. Because it is often difficult and uneconomic to remove metallic impurities from aluminum scrap by means of the usual melting and refining, the quality and type of aluminum scrap available frequently determines its use. Because of these limitations, most purchased aluminum scrap is used in the manufacture of castings. However, if scrap from one

**TABLE 8-4 ESTIMATED ALUMINUM USE IN PUBLIC CONSTRUCTION
PROGRAMS AS PERCENTAGE OF U.S. PRIMARY PRODUCTION,
SECONDARY RECOVERY, AND TOTAL NEW SUPPLY**

	1973	1974	1975	1976	1977
Primary Production					
% Federally owned construction	1.4	1.1	1.2	1.2	1.2
% State and locally owned construction	6.9	6.5	6.2	6.6	5.3
% Total public construction	8.3	7.6	7.4	7.8	6.5
Secondary Recovery					
% Federally owned construction	5.0	4.1	3.9	3.5	3.4
% State and locally owned construction	25.2	24.9	19.5	19.1	15.1
% Total public construction	30.2	29.0	23.4	22.6	18.5
Total New Supply					
% Federally owned construction	1.1	0.9	0.9	0.9	0.9
% State and locally owned construction	5.4	5.2	4.7	4.9	3.9
% Total public construction	6.5	6.0	5.6	5.8	4.8

type of wrought product can be segregated, the scrap can be remelted into ingots and used to produce more of the same product. For example, aluminum cans are being remelted into wrought ingots to produce more cans.

Major applications of some aluminum wrought and casting alloys in construction materials are shown in Table 8-5. It is to be noted that most construction materials are made of wrought alloys.

Aluminum scrap consumption and recovery data are presented in Table 8-6. Total scrap consumption increased by approximately 50 percent between 1971 and 1977. The percentages of total scrap consumption of primary metal production during this time frame are shown below.

1971	30.8 percent
1972	32.6
1973	32.5
1974	29.5
1975	37.3
1976	41.0
1977	39.5

TABLE 8-5. COMPOSITION LIMITS AND USES IN CONSTRUCTION MATERIALS OF SOME ALUMINUM WROUGHT AND CASTING ALLOYS⁽¹⁾ (WEIGHT - PERCENT)*

ALUMINUM ASSOC. DESIGNATIONS	ALUMINUM	COPPER	MANGANESE	MAGNESIUM	SILICON	OTHER CONSTITUENTS	APPLICATIONS
Wrought Alloy Series							
1000	99.0-99.75	0.2	0.05	0.05	1.0 incl. Fe	0.1 Zn, 0.05 Ti	Electrical Conductors
2000	Balance ⁽²⁾	19-68	12	18	1-25	13 Fe, 0.15 Ti, 2.3 Ni	Forgings
3000	DO ⁽²⁾	0.3	0.3-1.5	1.3	0.6	0.4 Zn, 0.1 Ti	Ductwork, Architecture, Roofing
4000	DO ⁽²⁾	0.25-1.5	0.1	1.3	4.5-13.5	1.3 Ni	Architectural Fittings
6000	DO ⁽²⁾	1.2	1.1	1.5	1.8	2.4 Zn, 1.0 Fe	Heavy Duty Structures, Pipe, Railing
Diecasting Ingot							
A380.1	DO ⁽²⁾	3.4	0.5	0.1	7.5-9.5	0.5 Ni, 0.1 Zn, 1.1 Fe	General Purpose Castings, Street Lamp Housings
413.2	DO ⁽²⁾	0.1	0.1	0.07	11-13		

(1) Maximum weight-percent of the casting ingot or of at least one of the wrought alloys in the series unless a range is given, in which case the upper and lower limits do not necessarily apply to the same alloy in the series.

(2) Balance after deducting percent composition of specified alloying constituents plus other normal impurities. Minimum impurities for casting alloys are normally specified but are not shown in this table.

*Source: "Aluminum," Mineral Commodity Profiles, MCP-14, Bureau of Mines, U.S. Dept. of the Interior, May 1978

TABLE 8-6. ALUMINUM SCRAP CONSUMPTION AND RECOVERY (1,000 SHORT TONS)*

YEAR	TOTAL SCRAP CONSUMPTION (1)	SCRAP CONSUMPTION (GROSS WT. BASIS) AS REPORTED				RECOVERY (RECOVERED METAL BASIS)		
		Total	Secondary Smelters	Primary Producers	Others	Total Industry (1)	From New Scrap (1)	From Old Scrap (1)
1971	1,210	1,005	640	171	194	1,050	834	216
1972	1,342	1,152	707	205	241	1,126	876	250
1973	1,472	1,262	737	213	313	1,235	977	258
1974	1,448	1,206	630	239	337	1,282	978	304
1975	1,448	1,232	612	343	278	1,236	899	337
1976	1,741	1,465	759	365	341	1,471	1,062	409
1977	1,795	1,521	841	426	254	1,557	1,082	475

(1) Estimates expanded from reported figures

*Source: "Aluminum Statistical Review 1977" the Aluminum Association, Inc.

During the same period, reported scrap consumption by secondary smelters increased by 31 percent and by primary producers by almost 50 percent. The relatively large change in the reported scrap consumption by primary producers is indicative of their increased interest and participation in the recycling of aluminum.

The last three columns in Table 8-6 distinguish between the consumption of new and old scrap on a recovered metal basis. The increase in the use of new scrap amounted to about 30 percent between 1971 and 1977 compared to a 120 percent increase in metal recovery from old scrap in the same time frame.

The consumption of purchased new and old scrap by primary producers and secondary smelters in 1975, 1976, and 1977 is shown in Table 8-7. New scrap generated and used by primary producers at their facilities is not included.

Purchases of new and old aluminum scrap by primary aluminum producers are grouped together with fabricators, foundries, and chemical plants. A breakout of the total scrap purchases by these groups is presented at the bottom of Table 8-7. It appears that primary producers do make significant purchases of scrap, although it does not follow that all do. It is known, for example, that some primary aluminum producers purchase aluminum cans for recycling into new cans. Other uses of purchased scrap by primary producers may be in their own secondary smelter operations or for the production of various aluminum alloys.

The scrap statistics indicate that the industry is now making greater use of recovered materials in aluminum production than in earlier years, and that this represents a trend rather than a short-time period phenomenon. Further, there is some evidence which suggests that a continued growth in secondary recovery can be achieved, i.e., that additional scrap is available which can be reasonably recovered. This is shown in Table 8-8, which compares estimates of aluminum old scrap generation and recovery.

PRIMARY SMELTING AND REFINING OF ALUMINUM

Aluminum metal is manufactured by the Hall-Heroult process, which involves the electrolytic reduction of alumina dissolved in a molten salt bath of cryolite (a complex of $\text{NaF} \cdot \text{AlF}_3$) and various salt additives.

The electrolysis is performed in a carbon crucible housed in a steel shell, known as a "pot." The electrolysis employs the carbon crucible as the cathode (negative pole) and a carbon mass as the anode (positive pole). Input materials consist of carbon anodes, carbon potliners (the cathodes), alumina (Al_2O_3), cryolite (Na_3AlF_6), aluminum

TABLE 8-7. CONSUMPTION OF PURCHASED NEW AND OLD ALUMINUM SCRAP
AND SWEATED PIG IN THE U.S., 1975-1977 (SHORT TONS)*

	SECONDARY SMELTERS	PRIMARY PRODUCERS ⁽¹⁾	TOTAL
1975			
New Scrap	422,397	472,664	895,061
Old Scrap	124,156	122,662	246,818
Sweated Pig	64,987	25,289	90,276
Total	611,540	620,615 ⁽²⁾	1,232,155
1976			
New Scrap	518,017	536,902	1,054,919
Old Scrap	158,869	152,371	311,240
Sweated Pig	82,106	17,197	99,303
Total	758,992	706,470 ⁽³⁾	1,465,462
1977			
New Scrap	559,847	511,160	1,071,007
Old Scrap	184,573	197,125	381,698
Sweated Pig	96,838	18,672	115,510
Total	841,258	726,957 ⁽⁴⁾	1,568,215

(1) Includes foundries, fabricators, and chemical plants

(2) (3) (4)	1975 ⁽²⁾	1976 ⁽³⁾	1977 ⁽⁴⁾
Primary Producers	342,810	365,190	425,733
Fabricators	98,001	121,212	137,720
Foundries	72,099	99,907	105,387
Chemical Plants	107,705	120,161	58,117

*Source: Bureau of Mines, U.S. Dept. of the Interior

TABLE 8-8. ESTIMATES OF ALUMINUM OLD SCRAP GENERATION AND RECOVERY
FOR 1975 (MILLIONS OF POUNDS - GROSS WEIGHT BASIS)*

MAJOR MARKET SOURCE	TOTAL OLD SCRAP BECOMING AVAILABLE(1)	NOT PRESENTLY RECOVERED			ACTUALLY RECOVERED IN 1975
		Difficult to Recover(2)	Possible Consumer Collection(3)	Possible Other Channels(4)	
Building & Construction	300	50	100	110	40
Transportation	900	200		450	250
Consumer Durables	500	100	150	150	100
Electrical	200	80		100	20
Machinery & Equipment	300	90		160	50
Containers & Packaging	1,600	800	625		175
Other	200	10		150	40
Total	4,000	1,330	875	1,120	675

(1) Estimated by Commercial Development Division, Alcoa

(2) Difficult to recover for technological and economic reasons (currently)

(3) Possibly recoverable through consumer collection centers from products that could be brought in by consumers

(4) Includes all other channels from all other sources

(5) Total for 1975 based on 10 months BOM data

*Source: Aluminum Association Casebook, Chap. 3 Appendix

fluoride (AlF_3), and calcium fluoride (CaF_2). The anodes are prepared in the carbon plant where petroleum coke is crushed, screened, classified, and mixed with a pitch binder.

When a sufficient quantity of aluminum metal has formed in a cell, it is drawn off into a transfer crucible and sent to the cast house where it is placed directly in a holding furnace or cast into pigs. Usually, the molten metal is fluxed before casting to remove minor impurities. Alloying metals are also added at this point. The casting and alloying is done prior to shipping for final product manufacture.

SECONDARY SMELTING AND REFINING OF ALUMINUM

The secondary aluminum smelting and refining industry is characterized by a large number of relatively small operations in urban areas throughout the United States. Many of these plants are engaged in only high grade scrap melting. Some primary aluminum producers also operate secondary smelters.

High grade aluminum scrap can be easily recycled by remelting in pot or rotary furnaces. The smelting of low grade scraps and foundry drosses is performed with reverberatory or rotary furnaces. Fluxing agents and alloying agents are charged with the scrap. Magnesium is removed by AlF_3 or Cl_2 demagging. Degassing is usually achieved simultaneously with the demagging operation. Upon completion of the smelting operation, the fluxing agent is skimmed and the purified metal melt is poured and cast into ingots. Common salt and potash mixtures are normally employed as fluxing agents.

Secondary aluminum smelting from low grade drosses containing 10 to 30 percent aluminum metal values requires pre-processing of the dross to enrich the aluminum metal content to about 75 percent. Either wet or dry processes may be employed. In the dry process, the dross material is crushed and comminuted in impaction or ball mills. The fines are removed, leaving enriched metal granules for smelting in reverberatory or rotary furnaces. Alternatively, the dross raw material may be processed by water washing in a rotating drum, where the water-soluble fluxing salts are removed. Wet processing is more commonly applied in relatively low volume dross processing plants.

The principal groups of raw materials for the secondary aluminum industry are (1) new clipping and forgings, (2) old casting and sheet, (3) borings and turnings, (4) remelted ingot and sweated pig, and (5) residues.

The main product line of secondary smelters is specification alloys (ingots or sows) and/or deoxidant (notched bar, shapes, or shot).

PROPOSED GUIDELINES

Construction materials designated as "aluminum" are usually made of an aluminum alloy. An aluminum alloy is defined by its chemical composition and allowable impurities. A particular alloy can generally be manufactured in a number of ways. At one extreme is the sole use of "earth" or "new" materials. On the other is the use of recovered material (old scrap) which has the exact chemical composition of the aluminum alloy required for the manufacture of the particular construction material. Between the two extremes are various combinations of "earth" materials and old scrap, new scrap and old scrap, and various types of old scrap.

Information which has been developed and is pertinent to the formulation of guidelines includes:

1. Required aluminum alloys can usually be produced in several ways.
2. Purchase of aluminum construction materials for public construction, and particularly for federally owned construction, represents only a small percentage of aluminum metal production.
3. The use of old and new scrap by the aluminum industry has shown a noticeable upward trend in recent years.
4. Primary producers (but not necessarily all) purchase significant quantities of old and new aluminum scrap.

Possible guidelines are:

1. The scrap content of aluminum construction products must be specified.
2. All construction products must contain at least x percent (e.g., 5-10 percent) of old scrap.
3. The metal from which construction materials are manufactured must be produced in secondary smelters.
4. The metal from which construction materials are manufactured must be produced from old scrap only.

The first guideline imposes a reporting requirement but is unlikely to have any further impact.

The second guideline will require material certification. It may eliminate primary producers who do not presently employ old scrap in their production process from bidding on government contracts. Conversely, the guideline may also act as a stimulus for these primary producers to utilize old scrap in their production process.

The third proposed guideline would eliminate "primary producers" as suppliers of aluminum construction materials for federally owned construction. Some primary producers, however, apparently also operate secondary smelters and these would remain competitive. At present, primary producers are the major suppliers of construction materials. This is not only related to metal production but also to the availability of the necessary milling, rolling, and fabricating facilities.

The last guideline is the most severe in terms of placing restrictions on the metal producers. The types of old scrap needed to produce the required aluminum alloy may not be readily available for purchase by many secondary smelters. The previously mentioned fabricating facility problems apply here as well.

The guideline recommended for implementation is to require that all construction products contain at least x percent (e.g., 5-10 percent) of recovered material. The precise percentage should be established initially through discussions with industry representatives. The percentage of recovered materials employed could be gradually increased over the years. As previously noted, this guideline would prevent some primary producers from bidding on government construction material contracts, i.e., those which do not presently employ recovered material in their production process. The number of firms which would be barred from bidding (assuming that they took no corrective action) would not appear to eliminate a competitive environment.

From data in Table 8-7, the percentages of old scrap (including sweated pig) of total purchased scrap consumption in the aluminum industry were calculated to be 27 percent in 1975, 28 percent in 1976, and 32 percent in 1977. Application of these percentages to the scrap consumption by primary producers yields the following estimates of old scrap consumption by primary producers:

1975	93,000 tons
1976	102,000
1977	136,000

Old scrap consumption is estimated to have represented the following percentages of total metal production by primary producers in 1975-1977.

1975	2.4 percent
1976	2.4
1977	3.0

The amounts of additional recovered materials which would be utilized as a result of the implementation of this guideline cannot be precisely quantified for the following reasons:

1. The continuing upward trend in the use of recovered material by the industry.
2. Some aluminum construction materials presently purchased by the government probably already contain recovered materials.
3. Old scrap consumption by primary producers is not reported.
4. The quantity of aluminum construction materials purchased by the government is relatively small.

The guideline would affect mainly primary producers. Total scrap use by primary producers is compared with total new metal production below for 1975, 1976, and 1977.

<u>Year</u>	<u>New Metal Prod.</u> ⁽¹⁾	<u>Scrap Consumption</u> ⁽²⁾	<u>%</u>
1975	3,879,000 tons	342,810 tons	8.8
1976	4,251,000	365,190	8.6
1977	4,539,000	425,733	9.4

(1) See Table 8-1

(2) See Table 8-7

The scrap consumption tonnages include both old and new scrap.

Assuming an initial guideline of 5 percent recovered material content in construction products and that aluminum construction products represent about 23 percent of the industry's total output, the additional consumption of old scrap as shown below would have resulted.

1975	23,000 tons
1976	25,000
1977	21,000

The relationship between private and public construction programs and the relatively modest use of aluminum products in public construction programs were discussed earlier. Accordingly, a guideline calling for a 5 percent recovered material content in aluminum construction materials would have resulted in the following increased consumption of recovered material from 1975 through 1977.

	<u>1975</u>	<u>1976</u>	<u>1977</u>
Federally Owned Construction	1,150 tons	1,000 tons	840 tons
State and Locally Owned Const.	5,750	5,500	3,780
Total Public Construction	6,900	6,500	4,620

Therefore, it is estimated that the implementation of this guideline would only result in a slight reduction in the waste stream.

Application of the guideline should be limited to mill orders or material purchases which exceed a stated quantity or value. It is suggested that two certification options be provided to industry: (1) certification that the delivered construction material contains the mandated amount of recovered material, and (2) the producing plant utilized, on the average, the mandated amount of recovered material in its operation during the preceding 3 or 6 months.

Section 9
USE OF FLY ASH IN CEMENT AND CONCRETE

INTRODUCTION

Fly ash may be incorporated into concrete either as a component of blended cement or as an admixture to an appropriately designed concrete mix. Employed in the latter role, the fly ash, because of its pozzolanic action, may replace a significant fraction of the Portland cement in concrete.

Known uses of fly ash in cement and concrete include the manufacture of blended cements, light-weight aggregates (e.g., used in the manufacture of masonry products), and soil-cement for highway construction. However, the use of fly ash to replace or supplement Portland cement in concrete represents the largest potential for fly ash in the particular construction categories considered in this study.

CEMENT PRODUCTION AND CONSUMPTION

The U.S. production of Portland and masonry cements as reported by the U.S. Department of the Interior¹⁴ is compared below with U.S. cement consumption presented in the Portland Cement Association's (PCA) Economic Report¹⁵ for 1972-1977. Quantities are expressed in 1,000's of short tons.

<u>Year</u>	<u>U.S. Department of the Interior</u>	<u>PCA</u>
1972	82,597	80,840
1973	85,513	86,253
1974	80,917	79,113
1975	68,139	67,243
1976	72,950	70,696
1977	NA	77,081

NA = not available

The data series coincide closely. Both show a significant drop from 1974 to 1975 followed by a gradual recovery trend.

14. "Cement in 1976," Mineral Industry Surveys, U.S. Dept. of the Interior, January 12, 1977.
15. "The U.S. Cement Industry, an Economic Report," Portland Cement Association, Second Edition, March 1978.

Consumption of cement by type of product for 1975¹⁵ is reported as follows:

<u>Cement Type</u>	<u>% of Consumption</u>
General use and moderate heat (Types I and II)	92.7
High early strength (Type III)	3.1
Oil well	1.7
White	0.5
Sulfate resisting (Type V)	0.5
Portland slag and pozzolan (blended cements)	0.5
Others	1.0

Only the blended cements contain slag or fly ash. Actually, however, many applications of Types I, II, and V cements permit the use of fly ash or slag either as an integral part of the cement or as a substitute for Portland cement in Portland cement concrete.

The small amounts of fly ash and slag employed in cement production are verified by a Department of the Interior industry survey,¹⁴ from which the following data are extracted.

	<u>1975</u>	<u>1976</u>
Total raw materials used in producing Portland cement in the U.S. (1,000's of short tons)	114,944	122,624
Blast furnace slag (1,000's of short tons)	465	435
Fly ash (1,000's of short tons)	180	264

Portland cement shipments in 1976¹⁴, by type of customer, are recorded as:

Building material dealers	5,497 x 10 ³ short tons	7.6%
Concrete product manufacturers	10,073	14.0
Ready-mixed concrete	46,666	64.9
Highway contractors	5,622	7.8
Other contractors	2,772	3.9
Federal, state & other govt. agencies	326	0.5
Miscellaneous, including own use	965	1.3
Total	<u>71,921</u>	

14. "Cement in 1976," Mineral Industry Surveys, U.S. Dept. of the Interior, January 12, 1977.

15. "The U.S. Cement Industry, an Economic Report," Portland Cement Association, Second Edition, March 1978.

By far the largest quantity of cement is shipped directly to ready-mix concrete facilities.

Average cement use by construction categories for the 1972-1976 time period¹⁵ was:

Public buildings	10%
Public Works	20%
Transportation	17%
Industrial-commercial	18%
Residential	28%
Miscellaneous	7%

The data indicate that almost one-half of U.S. cement consumption (47 percent) was utilized in federally/state/local owned construction, most of which may be impacted by federally funding.

Cement manufacture is a regional industry primarily because of the low value-to-weight ratio. Generally, cement plants tend to be located within 200 miles of their principal markets. Longer transport requirements result in excessive transportation costs except where barge shipment is available. Cement production capacity for 1976¹⁶ by EPA regions and states, together with 1976 cement consumption, is shown in Table 9-1. The wide geographic dispersal of the industry is borne out by the data.

FLY ASH PRODUCTION AND DISTRIBUTION

Coal, pulverized by grinding in advance of firing, contains some incombustible material, the amount varying with the source of coal. Two types of ash result from combustion. The coarser ash recovered is known as bottom ash; the bulk of the ash, known as fly ash, is collected from the flue gas by several rows of precipitators, and is either sluiced to a lagoon or collected dry in a silo. Fly ash constitutes approximately 80 percent of the total amount of ash produced.

15. "The U.S. Cement Industry, an Economic Report," Portland Cement Association, Second Edition, March 1978.

16. "Potential for Energy Conservation Through the Use of Slag and Fly Ash in Concrete" (Review Draft), Gordian Associates, Inc., September 1978.

TABLE 9-1. 1976 U.S. CEMENT PRODUCTION CAPACITY AND CONSUMPTION
(1000'S OF SHORT TONS)*

EPA REGION/STATES	CAPACITY	CONSUMPTION	EPA REGION/STATES	CAPACITY	CONSUMPTION
I	472	2,167	VI	13,380	11,673
Maine	472	308	Texas	8,928	6,482
Connecticut	0	563	Oklahoma	1,698	1,262
Massachusetts	0	810	Arkansas	1,245	886
New Hampshire	0	236	Louisiana	1,089	2,500
Rhode Island	0	141	New Mexico	420	543
Vermont	0	109			
II	4,684	3,439	VI	11,460	5,829
New York	4,684	2,088	Missouri	4,956	1,723
New Jersey	0	1,351	Iowa	3,093	1,849
			Kansas	2,386	1,228
III	12,890	5,974	Nebraska	1,025	1,029
Pennsylvania	9,499	2,850	VIII	3,844	3,658
Maryland	1,861	1,188	Colorado	1,714	1,197
Virginia	1,530	1,598	South Dakota	570	376
Delaware	0	142	Utah	710	919
District of Columbia	0	196	Montana	650	336
			Wyoming	200	418
IV	16,019	11,822	North Dakota	0	412
Alabama	3,902	1,361	IX	12,215	8,796
Florida	3,957	3,389	California	10,095	7,316
South Carolina	2,539	782	Arizona	1,720	1,117
Tennessee	2,004	1,310	Nevada	400	363
Georgia	1,683	1,644			
Mississippi	664	831			
Kentucky	660	1,046			
North Carolina	610	1,459			
V	16,237	13,959	X	3,399	2,963
Michigan	6,442	2,595	Washington	1,789	1,167
Indiana	3,496	1,682	Hawaii	770	327
Illinois	2,810	3,759	Oregon	630	794
Ohio	2,451	2,770	Idaho	210	512
Wisconsin	374	1,602	Alaska	0	163
Minnesota	664	1,551	Total U.S.	94,600	70,280

*Source: "Cement in 1976," Mineral Industry Surveys, U.S. Department of the Interior, January 12, 1977.

The largest sources of fly ash are those thermal power plants which employ bituminous coal as their primary fuel. Estimates of the quantity of fly ash recovered range around 8 percent by weight of the coal burned. Estimated fly ash generation based on bituminous coal consumption in the U.S. in 1976¹⁶ is shown by EPA regions and states in Table 9-2. The amount of fly ash produced annually from this source has probably increased since 1976 and can be expected to continue to increase as power plants are converted from oil or gas to coal.

Cement consumption and fly ash generation in the 10 EPA regions are compared below using 1976 data. Quantities are expressed in 1,000's of short tons.

<u>EPA Region</u>	<u>Cement Consumption</u>	<u>Fly Ash Generated</u>
I	2,167	60
II	3,439	660
III	5,974	6,008
IV	11,822	9,015
V	13,959	10,570
VI	11,673	0
VII	5,829	2,521
VIII	3,658	219
IX	8,796	85
X	2,963	0

No fly ash was produced in EPA regions VI and X, and less than 100,000 short tons were produced in EPA regions I and IX. The bulk of the fly ash is found in EPA regions III, IV, and V, which encompass the mid-western and south-eastern states.

FLY ASH AND CEMENT UTILIZATION

Total fly ash collection and utilization data are available for 1977¹⁶ and are presented in Table 9-3.

There is a significant difference between the total amount of fly ash produced listed in Table 9-3 and that presented in Table 9-2. The data were obtained from different sources and are for different years, the former being 1977 and the latter being 1976. Further, the data in Table 9-2 are computed values, whereas the information in Table 9-3 apparently is based on reported fly ash recovery and disposal, and may include fly ash from other than bituminous coal.

16. "Potential for Energy Conservation Through the Use of Slag and Fly Ash in Concrete" (Review Draft), Gordian Associates, Inc., September 1978.

TABLE 9-2. ESTIMATED FLY ASH GENERATED IN THE U.S. IN 1976
FROM BITUMINOUS COAL (1000'S OF SHORT TONS)*

EPA REGION/STATES	FLY ASH	EPA REGION/STATES	FLY ASH
I	60	VI	0
Maine	0	Texas	0
Connecticut	0	Oklahoma	0
Massachusetts	0	Arkansas	0
New Hampshire	60	Louisiana	0
Rhode Island	0	New Mexico	0
Vermont	0		
II	600	VII	2,521
New York	458	Missouri	1,645
New Jersey	202	Iowa	469
		Kansas	274
		Nebraska	133
III	6,008	VIII	219
Pennsylvania	2,905	Colorado	72
Maryland	366	South Dakota	2
Virginia	425	Utah	145
Delaware	2,250	Montana	0
District of Columbia	62	Wyoming	0
		North Dakota	0
IV	9,015	IX	85
Alabama	1,447	California	0
Florida	555	Arizona	19
South Carolina	439	Nevada	66
Tennessee	1,682		
Georgia	1,168		
Mississippi	126		
Kentucky	2,031		
North Carolina	1,567		
V	10,570	X	0
Michigan	1,674	Washington	0
Indiana	2,274	Hawaii	0
Illinois	1,950	Oregon	0
Ohio	3,848	Idaho	0
Wisconsin	690	Alaska	0
Minnesota	134		
		Total U.S.	29,138

*Source: Calspan estimates based on the bituminous coal consumption data given in
"Potential for Energy Conservation Through the Use of Slag and Fly Ash in Concrete" (Review Draft),
Gordian Associates, Inc., September 1978
and using an average fly ash generation rate of 8 percent of the weight of coal burned.

**TABLE 9-3. FLY ASH COLLECTION AND UTILIZATION
(MILLIONS OF SHORT TONS)**

Total Fly Ash Collected	48.5	
Ash Utilized	6.3*	
Commercial Utilization		
Mixed with raw material before forming cement clinker	0.4	(7%)
Mixed with cement clinker or mixed with cement (Type 1-P)	0.3	(5%)
Partial replacement of cement in concrete and blocks	1.6	(25%)
Lightweight aggregate	0.1	(2%)
Fill material for roads, construction sites, land, reclamation, dikes, etc.	1.3	(20%)
Stabilizer for road bases, parking areas, etc.	0.2	(3%)
Filler in asphalt mix	0.1	(2%)
Miscellaneous	0.2	(3%)
Ash Removed from Plant Sites at No Cost to Utility	0.4	(7%)
Ash Utilized from Disposal Sites After Disposal Costs	1.6	(26%)

*Due to rounding errors, the figures below total 6.2 rather than 6.3.

Regardless, it is evident that sufficient fly ash is generated annually to meet all potential needs of the cement and concrete industries. The total availability of fly ash can be misleading, however, since its use is dependent on fly ash quality, material performance, location/cost, and engineer bias. It is believed that the latter two factors represent the significant obstacles in the way of expanded use of fly ash in cement and concrete.

The EPA regions and states in which fly ash is generated are shown in Table 9-2. Current and projected future major construction programs receiving Federal Government support and requiring relatively significant amounts of cement/concrete are more difficult to identify.

One major usage of cement is in highway construction. It is assumed that highway construction, although financed largely through a trust fund, falls within the province of the guidelines. U.S. average

usage factors for cement and for concrete pipe, expressed in tons/million dollars of contracted highway construction cost, are shown in Table 9-4.

TABLE 9-4. U.S. AVERAGE HIGHWAY CONSTRUCTION USAGE FACTORS FOR CEMENT AND CONCRETE PIPE (SHORT TONS/MILLION DOLLARS OF CONTRACT CONSTRUCTION COST)*

	CEMENT**	CONCRETE PIPE***
1968-69-70	1,794	393
1969-70-71	1,747	402
1970-71-72	1,562	381
1971-72-73	1,391	333
1972-73-74	1,281	334
1973-74-75	1,076	270
1974-75-76	938	247

*Source: "Highway Construction Usage Factors for Cement, Bitumens, Concrete Pipe and Clay Pipe, 1974-75-76," U.S. Department of Transportation, Federal Highway Administration.

**Includes portland and natural cement used for paving, structures, and all other highway construction purposes except pipe.

***Includes both plain and reinforced concrete pipe. Reinforcing included in the concrete pipe factors amounts to about 2 percent by weight.

As shown subsequently, the steep decline in the quantity of cement usage per million dollars of construction cost over the years is due in part to reduced cement usage. Also, however, it is accounted for by the fact that the cost of construction, other than cement, has risen at a much more rapid pace than the price of cement.

Cement usage for interstate and other federal-aid primary highway systems is somewhat above and concrete pipe usage is below the national averages. Data are reported as follows¹⁷ in terms of tons per million dollars of construction costs.

17. "Highway Construction Usage Factors for Cement, Bitumens, Concrete Pipe and Clay Pipe, 1974-75-76," U.S. Dept. of Transportation, Federal Highway Administration.

	<u>Cement</u>	<u>Concrete Pipe</u>
1973-74-75	1,349	223
1974-75-76	1,206	201

Estimated construction expenditures for all public highways (federal, state and local funds excluding cost of right-of-way and engineering) for 1969-1977 are shown below:

1968	\$8.112 billions	1974	\$10.962 billions
1969	8.128	1975	12.020
1970	9.235	1976	12.119*
1971	9.868	1977	12.371**
1972	9.789		
1973	9.722		

*Preliminary

**Forecast

Combining these data with those contained in Table 9-4 yields the following average, annual usages of cement and concrete pipe for highway construction.

	<u>Cement</u> <u>(1000's of tons)</u>	<u>Concrete Pipe</u> <u>(1000's of tons)</u>
1968-69-70	15,234	3,337
1969-70-71	15,858	3,649
1970-71-72	15,043	3,669
1971-72-73	13,622	3,261
1972-73-74	13,012	3,393
1973-74-75	11,730	2,943
1974-75-76	10,975	2,890

The average annual cement usage over this time period was $13,639 \times 10^3$ tons ($\sigma = 1,852$), that of concrete pipe $3,306 \times 10^3$ tons ($\sigma = 307$). The average quantities appear reasonable estimates for the immediate future use of cement and concrete pipe in highway construction activities. This estimate of cement usage checks closely with the estimate of cement consumption for transportation shown earlier under "Cement Production and Consumption."

The remainder of cement usage in federally supported construction programs is for public works and public housing. A large portion of the former, particularly as it pertains to the types of projects which employ significant quantities of cement, is believed to fall under the aegis of the Corps of Engineers. Historically, the Corps has permitted and, in fact, encouraged the use of fly ash in its dam construction programs where fly ash of suitable quality is available within a reasonable distance from the construction site. "Reasonable" in this case is defined by the relative costs of fly ash and cement at the construction sites.

Fly ash employed in public housing may encounter opposition because it tends to reduce the early strength of concrete which in turn may impact on the construction schedule. Apparently, however, it is possible to meet early strength requirements by employing the reduced water requirement, imparted by fly ash to concrete mix, as a means for formulating a concrete mix that includes fly ash.

TECHNICAL CONSIDERATIONS

The following discussion of the problems, advantages, and disadvantages of the use of fly ash in cements and concrete are based largely on the proceedings of the Energy and Resource Conservation in the Cement and Concrete Industry Seminar held in Ottawa in November 1976.¹⁸

When used in mass concrete where early strength is not critical and low heat performance is sought, or in steam-cured concrete, fly ash can replace an equal quantity of cement. The U.S. Corps of Engineers¹⁹ indicated that a 30 percent substitution of fly ash for cement has been used for the interior construction of dams and 20 percent substitution for exterior dam construction.*

*Current ASTM specification limits the pozzolan constituent to a range of 15-40% of the finished cement in blended cements. Virtually no loss in strength occurs at early ages if replacement is held to about 10 percent.

18. "Energy and Resource Conservation in the Cement and Concrete Industry," Proceedings of a Seminar Sponsored by Canada Centre for Mineral and Energy Technology (CANMET) and Office of Energy Conservation, Dept. of Energy Mines and Resources, Ottawa, Ontario November 8, 9, 1976.
19. Telcon with U.S. Army Corps of Engineers, Washington, D.C. October 1978.

Fly ash of good quality can be shipped relatively long distances where it ranks in value with cement. However, where fly ash is used in normal structural concrete and where early strength is required, considerably more ash must be used than the amount of cement removed. In this use, fly ash of good quality has a value of up to one-half that of portland cement, reducing the potential marketing distance accordingly.

The potential of fly ash as a raw material in the manufacture of sintered lightweight aggregate is well recognized. Unburned carbon in fly ash reduces the amount of fuel required in production. The latter benefit over other means of lightweight manufacture will increase in proportion as fuel costs increase.

Despite this promising outlook, many past attempts at sintered aggregate manufacture using fly ash have ended in failure. Failures have been due to technical reasons (control of carbon content and fineness of the fly ash) and economic reasons (a plant should have a high capacity, preferably over 300,000 tons per year).

High carbon content and low fineness are usually undesirable features in fly ash for pozzolanic applications or aggregate production. Considerable variation in the quality of fly ash as measured by these parameters can occur not only between sources of fly ash but also in a given source of fly ash. Factors which contribute to this variability include:

1. The extent to which the coal is pulverized prior to firing.
2. The firing cycle during which fly ash is collected, e.g., poorer quality of fly ash is usually generated during start-up and when the efficiency of burning is low.
3. Provision of traps for tramp iron, etc., in fly ash handling systems, excluding such material from supplies stored for marketing.

The Corps of Engineers¹⁹ indicates that it specifies performance requirements rather than material content for most concrete construction. It is up to the competing contractors to employ fly ash as they see fit, i.e., to the extent that it is to their greatest economic advantage.

19. Telcon with U.S. Army Corps of Engineers, Washington, D.C., October 1978.

The Corps of Engineers does, however, sample and test available fly ash within a reasonable distance from the construction sites to determine its suitability as a construction material. Such tests are made prior to each construction program. There is no nationwide or even regional listing of acceptable fly ash supplies for concrete work. This is probably in recognition of the fly ash variability noted previously. Fly ash, where employed, is generally stored in silos and metered and combined with cement and aggregates in situ.

PROPOSED GUIDELINES

Careful selection of fly ash from a source of low variability, combined with adequate quality control and concrete mix proportioning, can result in a durable product at reduced material costs.

Guidelines which encourage the use of fly ash in concrete, particularly where it is used as a Portland cement substitute, would obviously have a depressing effect on the Portland cement industry.

Fly ash sources, where extant, are generally available on an equal basis to all contractors who may compete for government financed (in whole or in part) construction activities in a given area.

The use of fly ash, as a substitute for Portland cement, could probably be set at 5-10 percent wherever cements of Types I and II are used without affecting performance. Primary uses of fly ash, however, are in construction projects such as dams and road substrata where the advantages provided by the use of fly ash far outnumber their disadvantages. The Corps of Engineers already encourages the use of fly ash in many of its programs. Greater use of fly ash in road construction will depend to a considerable degree on convincing state highway engineers of the benefit of its application.

The current approach used by the Corps of Engineers may be a model for the proposed guidelines, namely

1. Determine that fly ash of a suitable quality and in sufficient quantity is available in the construction area.
2. Specify that fly ash is an acceptable cement substitute material.
3. Employ performance rather than material specification.
4. Rely on the economics (i.e., the relative price advantage of fly ash vs Portland cement) to further the use of fly ash in concrete.

Section 10
CONSTRUCTION PAPER AND BOARD

INTRODUCTION

Construction paper and boards are not standard products. Materials and production processes employed in their manufacture differ among manufacturers. Even within the output from a particular manufacturing plant, materials employed, including types of waste materials, can vary depending on the cost and availability of particular waste materials at any point in time. The construction materials which are included in this category and their usage in construction are described below.

MATERIAL DESCRIPTION

The major construction paper products are sheathing paper, roofing felts, asbestos paper and asbestos-filled paper. Also included in this product category are floor covering (e.g., carpet felt, wet base for enameled floor covering and linoleum), automotive felts, felts used for deadening, industrial, pipe covering and refrigerators, insulating paper blankets, and other building paper such as saturating screenings.

Construction board products can be divided into three categories:

- Insulating boards for retail use
- Insulating boards for industrial use
- Hardboard

Insulating boards for retail use which are designed for interior application include building and wallboard, sound deadening board, tile, planks, trim, and moldings. Exterior applications of insulating boards consist of sheathing board, shinglebacker, roof insulation, roof deck insulation, and fiberboard formboard.

Insulating boards for industrial uses include material employed for further manufacture, processing, or assembly. Examples are insulating siding base, trailer board, backer board for metal siding, expansion joint strips, and other industrial uses such as in automobiles and furniture.

Hardboard is of two types: treated or tempered, and not treated or tempered.

The following information is provided to illustrate the variations in types and quantities of waste paper used in the manufacture of these products.

Gypsum wallboard is coated on both sides with paper, 100 percent of which is derived from waste paper. Core material contains very little, if any, paper.

Cellulose insulation is made by running newsprint through a complex "defiberer" and shredding operation. Chemicals are then added so that the final product (fine thermal insulation) contains 16 to 20 percent chemicals by weight, the remainder being paper. It is estimated that between 480,000 and 615,000 short tons of newsprint were used in the manufacture of this product in 1977.

Roofing felt can be made from corrugated paper waste (50 - 60 percent) and wood, or alternatively, from a combination of newsprint (38 percent), corrugated waste paper (32 percent) and softwood sawdust (30 percent).*

Ceiling tile may contain 0 to 5 percent of waste by weight, mineral wool panels 10 percent of paper/corrugated by weight, and exterior insulation sheathing board 5 percent of waste paper by weight.

Finally, there is one U.S. manufacturer of exterior and interior construction boards whose product lines are made largely from waste paper.

It should be noted that increased use of wastepaper would in some cases reduce the utilization of other waste materials.

U.S. PRODUCTION OF CONSTRUCTION PAPER AND BOARDS

Production of construction paper and boards for 1970 through 1977 is summarized in Table 10-1. Production rose between 1970 and 1973 and then declined during the following two years. Production recovered to record levels in 1976 and 1977.

A breakdown of production, by major product categories, for 1975 and 1976, is shown in Table 10-2. In terms of tonnage, construction boards represent about two-thirds and construction paper one-third of the total output.

*The amounts of materials of various types used in the manufacture of paper-type construction products were obtained through private communications with industry representatives.

**TABLE 10-1. CONSTRUCTION PAPER AND BOARD PRODUCTION
(1,000 SHORT TONS)***

	1970	1971	1972	1973	1974	1975	1976	1977
Construction Paper	1,594	1,837	1,915	1,858	1,845	1,616	1,832	1,792
Construction Board								
Insulating Board	1,219	1,446	1,529	1,547	1,295	1,249	1,441	1,409
Hardboard	1,463	1,718	1,908	2,001	1,978	1,784	2,145	2,279
Subtotal	2,682	3,164	3,437	3,548	3,273	3,033	3,586	3,688
Grand Total	4,276	5,001	5,352	5,406	5,118	4,649	5,418	5,480

*Source: Bureau of the Census, U.S. Department of Commerce

**TABLE 10-2. PRODUCTION OF CONSTRUCTION PAPER AND BOARD
(SHORT TONS)***

	1975	1976
Construction Paper		
Sheathing Paper	15,800	22,067
Roofing Felts	1,401,510	1,553,320
Asbestos Paper and Asbestos Filled Paper	90,518	114,181
Other	107,714	142,593
Total	1,615,542	1,832,161
Construction Boards		
Insulating Boards for Retail Use		
Interior Products	421,581	481,969
Exterior Products	659,913	766,265
Subtotal	1,081,494	1,248,234
Insulating Boards for Industrial Use	167,317	193,105
Insulating Boards Total	1,248,811	1,441,339
Hardboard		
Treated or Tempered	718,039	832,808
Not Treated or Tempered	1,065,492	1,312,314
Hardboard Total	1,783,531	2,145,122
Construction Board Total	3,032,342	3,586,461
Construction Paper and Boards Grand Total	4,647,884	5,418,622

*Source: "Pulp, Paper and Board," Summary for 1976, Current Industrial Reports M26A(76)-13, Bureau of Census, U.S. Department of Commerce, Issued August 1977.

USE OF CONSTRUCTION PAPER AND BOARDS IN PUBLIC CONSTRUCTION

The primary application of these construction materials is in residential and nonresidential buildings. The relative construction values of federally owned and state and locally owned buildings of total U.S. construction of residential and non residential buildings are used to estimate the use of the construction products in public construction.

The percentages of public building construction of total (private and public) building construction are shown below.

	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>1977</u>
% Federally owned Bldgs.	1.3	1.6	1.9	1.7	1.9
% State and Locally owned Bldgs.	11.7	14.2	15.4	11.5	9.9
% Private Bldgs.	87.0	84.2	82.7	86.8	88.2

These percentages are combined with the data in Table 10-1 to yield the estimated tonnages of construction paper and boards employed in public construction.

These are:

	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>1977</u>
<u>Construction Paper (1,000 short tons)</u>					
Federally owned construction	24	30	31	31	34
State and Locally owned construction	217	262	249	211	177
<u>Construction Board (1,000 short tons)</u>					
Federally owned construction	46	52	58	61	70
State and Locally owned construction	415	465	467	412	365

ESTIMATED PROCUREMENT FOR PUBLIC CONSTRUCTION

The quantities of construction paper and boards used in public construction appear to be relatively modest. The estimated quantities of construction paper and boards installed per million dollars of public building construction are:

	<u>Construction Paper</u>	<u>Construction Board</u>
1973	19 short tons	35 short tons
1974	19	34
1975	18	34
1976	18	36
1977	17	35

The quantities of construction paper and board products per million dollars of public building construction remained relatively constant throughout this period of time.

As previously noted, different manufacturers employ different types and quantities of waste materials to produce their competing products. Some manufacturers are presently set up to use slightly different mixes of waste materials in their production processes, the selection being based on the availability and cost of usable waste products.

It appears unlikely that the relatively small government purchases provide sufficient incentive for a manufacturer to modify his production process(es) in order to accommodate a small increase in the use of waste materials.

CANDIDATE GUIDELINES

The industry presently makes extensive use of recovered materials and other wastes (e.g., sawdust). The mix of waste materials used by manufacturers in the production of a particular material varies depending in part on their availability and cost and the proprietary production processes employed.

Government purchases account for a relatively small portion of industry sales. It is doubtful whether Government purchases could provide sufficient incentives for the industry to make significant changes in its production processes or whether, in fact, individual plants could do so and maintain their identity. Consideration of the preceding, together with the already extensive use of waste products by the industry, leads to the conclusion that no substantive guidelines are required for these products.

Section 11
USE OF WASTE RUBBER IN HIGHWAY CONSTRUCTION

INTRODUCTION

In recent years, there has been a growing interest in the use of rubber from discarded tires in various highway construction and maintenance operations. Applications of asphalt-rubber materials currently being examined include:

Seal coats
Joint and crack fillers
Strain relieving interlayers

In particular, the use of an asphalt-rubber paving composition as the binder in a seal coat and/or interlayer application has been the subject of extensive field trials in recent years. The Federal Highway Administration has funded studies in several states on the use of tire chips in asphalt under Demonstration Project No. 37. The results of this demonstration program are still being evaluated. In a status report published in July 1978, the comments of investigators from 18 states were generally favorable although some observers noted no differences in the performance of control sections which were installed using conventional materials and test sections installed using asphalt-rubber mixtures.

ASPHALT-RUBBER PAVING METHODS

There are two major methods in use for incorporating waste rubber into asphalt paving operations. Both methods use discarded tires as the major source of rubber, but they differ in the way the rubber is prepared and then mixed with the asphalt.

In the first method, a typical specification requires that "...the rubber shall be a dry free flowing blend of 40% powdered devulcanized rubber and 60% ground vulcanized rubber scrap specially selected to have a high natural rubber content. It shall be free from fabric, wire, or other contaminating materials except that a small quantity of mineral powder may be included to prevent caking of the particles."²⁰ For this method, the sieve analysis is specified as follows:

20. Personal communication. Robert C. Ziegler, Calspan Corporation, to William H. Clark III, N.Y.S. Thruway Authority, Albany, N.Y. 15 December 1978.

<u>Screen</u>	<u>% Retained</u>
10	0
30	20-40
50	40-60
100	5-15
pan	10-25

The second method requires that "...the rubber shall be a good quality ground tire rubber, dry and free flowing. The specific gravity of the rubber shall be 1.15 ± 0.02 and shall be free from fabric, wire, or other contaminating materials except that up to 4 percent of calcium carbonate shall be included to prevent the particles from sticking together." The corresponding sieve analysis is specified as:

<u>Screen</u>	<u>% Passing</u>
16	95% Min.
25	10% Max.

Because the first method requires that part of the rubber be devulcanized, the cost of the prepared rubber is somewhat higher than that required for the second method. Recent inquiries indicated that rubber of type 1 was \$0.30/lb. compared to \$0.20/lb. for type 2 rubber.

In the preparation of the binder for the first method, an asphalt-oil blend is heated to at least 400°F and thoroughly mixed before the rubber is added. The rubber is added in amounts up to 22 to 24 percent. Adequate agitation of the liquid blend must be maintained to insure proper dispersion and mixing. The asphalt-rubber mix is applied at a temperature of 375°F to 425°F at a minimum rate of 0.6 gallon per square yard.

For the second method, the binder is prepared by combining the rubber, in amounts of 23 to 27 percent by weight, with asphalt at a temperature between 350°F and 450°F. Following mixing, the blend is diluted with a kerosene-type diluent. The asphalt-rubber mix is applied at a temperature of 300°F to 350°F at the rate of 0.4 to 1.0 gallon per square yard.

Perhaps the most common use of the asphalt-rubber mixtures is as a stress absorbing membrane interlayer (SAMI). In this application, the mixture is applied over old deteriorated pavement or base. Later a friction course of asphaltic concrete is generally applied. The SAMI has shown to be effective in preventing reflective cracking of the final surface layer due to the cracks in the old underlaying pavement.

Since some special equipment is required for blending and applying the asphalt-rubber mixture, a capital investment is required on the part of the paving contractor. The cost of the asphalt-rubber mix is 2 to 3 times that of asphalt alone.

ASPHALT SALES IN THE U.S.

Sales of petroleum asphalt for consumption in the U.S. by type and principal use are shown in Table 11-1 for the years 1972-1976. Total sales of petroleum asphalt as well as the use of asphalt for paving have declined during the past 2 years, i.e., 1975 and 1976, from a high in 1973. The proportionate amount of asphalt used for paving, as a percentage of total sales, remained constant throughout the 5-year period at 78-79 percent.

RUBBER RECYCLING

Recycled rubber statistics for the years 1973-1977 are shown in Table 11-2. Listed under Consumption, item i, Rubber Surfacing, includes recycled tires used in paving products. The statistics do not include the approximately 50 million or more tires which are retreaded each year.

However, the amount of rubber recycled or the recycling capacity, even when considered jointly with tires destined for retreading, still represents only a small percentage of the 200 to 300 million tires discarded each year. The remainder is added to the already existing piles of tires strewn everywhere. It has been estimated that there are over 2 billion scrap tires presently in storage or littering the landscape.²¹

POTENTIAL BENEFITS

Although the use of discarded tires in asphalt is still under investigation and evaluation, it is possible to bound potential benefits by means of a simple parametric analysis. Benefits in this context are defined as the removal of discarded tires from the nation's waste stream.

The independent variable in the analysis is the amount of asphalt replaced by ground-up tires in the paving mixture. The dependent variable is the amount of waste rubber utilized, i.e., the number of tires consumed.

21. "Ways to Use Waste Products in Highway Construction," Prepared by Task Force 16 Subcommittee on New Highway Materials of the Joint Cooperative Committee of American Association of State Highway and Transportation Officials, American Road and Transportation Builders Association.

TABLE 11-1. SALES OF PETROLEUM ASPHALT FOR CONSUMPTION IN THE UNITED STATES,
BY TYPE AND PRINCIPAL USE¹ (SHORT TONS)*

	1972	1973	1974	1975 ²	1976
United States, Total	31,120,928	34,333,031	31,035,026	27,495,156	27,300,148
By Type:					
Asphalt Cements and Fluxes	24,728,001	27,370,153	25,129,258	22,113,178	21,882,700
Emulsified Asphalts	2,532,833	2,742,732	2,526,991	2,309,812	2,379,556
Cutback Asphalts	3,860,094	4,220,146	3,358,777	3,072,166	3,037,892
By Principal Use:					
Paving Products	24,305,490	27,040,551	24,641,766	21,592,860	21,474,850
Roofing Products	5,346,860	5,677,335	4,814,851	4,803,164	4,791,987
All Other Products	1,468,578	1,615,145	1,578,409	1,099,132	1,033,311

1. Excludes domestic bituminous limestone and sand stone, gilsonite and road oil.

2. Revised.

*Source: Sales of Asphalt in 1976, Mineral Industry Surveys, U.S. Department of the Interior, Bureau of Mines, 27 June 1977.

TABLE 11-2. RECYCLED RUBBER STATISTICS, 1977*

CONSUMPTION	1977		1976	1975	1974	1973
	MILLION POUNDS	%	%	%	%	%
a) Tires Repair Material	129.9	53.1	56.0	58.8	58.8	58.8
b) Inner Tube Reclaim	21.0	8.6	8.8	10.3	6.3	8.4
c) Ground Crumb	35.2	14.4	10.2	9.6	6.7	N.A.
d) Auto Mats, Mechanicals	20.2	8.3	12.8	8.3	13.5	15.4
e) Heels, Soles, Footwear	0.2	—	0.1	0.2	0.3	0.1
f) Cements, Dispersions	5.6	2.3	2.1	4.1	4.6	4.2
g) Hose, Belting Packing	2.4	1.0	0.9	0.5	0.7	1.7
h) Mechanicals (not auto)	16.1	6.6	7.0	5.7	7.4	7.7
i) Rubber Surfacing	6.5	2.7	0.8	1.2	1.2	2.5
j) All Other	7.4	3.0	1.3	1.3	0.5	0.7
TOTAL - Million Pounds	244.5	100.0	217.9	223.1	259.8	285.6
SCRAP RUBBER PROCESSED	259.0		221.0	188.6	263.3	287.7
OPERATING CAPACITY (300 day operation)	289.6		263.9	247.0	325.3	299.4

N.A. = Not Available

*Source: Technical Committee Survey Results, Table 1, Rubber Recycling Division, A Division of National Association of Recycling Industries, Inc.

For the purpose of the analysis, it is assumed that 23,800,000 short tons of asphalt paving mixture are used annually. This represents the average quantity for the 1972-1976 time period. It is further assumed that a tire will yield 10 pounds of ground rubber after removal of the bead and the major part of the fabric. The quantity of ground rubber substituted in the asphalt paving mixture is varied from 0.01 percent to 25 percent.

The results of this analysis are shown in Table 11-3. According to Table 11-2, 3,250 short tons of rubber are presently used for rubber surfacing. This is equivalent to substituting, on the average, 0.014 percent of ground rubber in the total quantity of asphalt paving mixtures used in the U.S. and represents approximately 650,000 tires.

TABLE 11-3. POTENTIAL USES OF DISCARDED TIRES IN ASPHALT PAVING MIXTURES

GROUND RUBBER SUBSTITUTE (%)	RUBBER REQUIRED (Short Tons)	NO. OF TIRES
0.01	2,380	476,000
0.02	4,760	952,000
0.05	11,900	2,380,000
0.10	23,800	4,760,000
0.25	59,500	11,900,000
0.50	119,000	23,800,000
1.00	238,000	47,600,000
5.00	1,190,000	238,000,000
10.00	2,380,000	476,000,000
15.00	3,570,000	714,000,000
20.00	4,760,000	952,000,000
25.00	5,950,000	1,190,000,000

It is estimated that the substitution of ground rubber in paving asphalt in amounts of 2 to 3 percent would consume all the tires discarded annually. While this would provide a means for disposing of the tires, it would have no noticeable beneficial effects on the pavement.

The amount of rubber which must be added to the asphalt mixtures to obtain improved performance varies between 6% and 25%, depending on application (e.g., as a stress-absorbing membrane, or as a wearing course).

The percentage of all asphalt paving where the addition of rubber could provide enhanced performance is not known. If we assume that this is the case in 10 percent of all asphalt paving and that, on the average, the average rubber addition is 25 percent, the total number of tires consumed would be 120 million. This quantity is 183 times greater than current tire use for this application. It is readily apparent that any significant application of rubber-asphalt paving mixtures would eliminate large numbers of tires from the waste stream.

The use of rubber in asphalt paving mixtures does not come free. Plants for grinding rubber require substantial investments. Extra equipment is also required by contractors applying the rubber-asphalt mixture.²⁰

The purpose behind capital investment decisions is to protect and increase the profit-making ability of a corporation. The private sector will not make investments necessary to implement the rubber-asphalt paving concept until the profit potential exists. Basic here is the existence of a market place for the materials and services being offered.

The use of rubber-asphalt pavement mixtures is almost certain to result in higher prices than regular asphalt, particularly during the initial years of implementation. Therefore, the government would have to not only guarantee (i.e., require) the use of asphalt-rubber pavement mixtures but also indicate that it would absorb the incremental costs associated with the use of the mixture.

GUIDELINES

Experimental uses of rubber-asphalt paving mixtures have shown encouraging results. Widespread application of such paving mixtures has the potential to remove a significant number of discarded tires from the nation's waste stream.

Increased use of this paving mixture will require capital investments in two areas in the private sector of the economy: (1) the establishment of plants to prepare the ground rubber, and (2) the modification of equipment used to spread the paving mixture.

Guidelines promulgated for the use of this paving mixture must guarantee the private sector a market for materials and services. A major obstacle is that most highway construction and repair contracts are let by the states. The states may hesitate to utilize the new paving mixture because of incomplete or inconclusive test results and higher costs which may be incurred as a result of its use. A large-scale promotion and education program appears necessary to sell this concept to the states.

Implementation of a specific guideline(s) must await the completion and evaluation of demonstration projects currently being conducted by the Federal Highway Administration.

20. Personal communication. Robert C. Ziegler, Calspan Corporation, to William H. Clark III, N.Y.S. Thruway Authority, Albany, N.Y. 15 December 1978.

The present production capacity for ground rubber is inadequate to satisfy significantly increased demand. Any guideline must, therefore, provide for a gradual increase in the use of rubber in pavement. Further, it must provide sufficient guarantees for the employment of such material (including the absorption of higher costs) to stimulate the private sector to enlarge its production capacity.

Section 12

GLASS

INTRODUCTION

A number of products containing waste glass have been fabricated and evaluated in laboratory and small-scale demonstrations. These include:

- Glass polymer composite sewer pipe
- Glass-wool insulation
- Lightweight aggregate
- Brick
- Floor tile
- Glasphalt bituminous pavement

The processes employed in the manufacture of products containing waste glass are in various stages of development. None of the products are presently commercially available, and none are expected to be in the immediate future.

As a result, building materials containing recycled glass are not of immediate relevancy to this study. The following discussion addresses some of the technological and economic aspects of the use of waste glass in construction material and its potential significance for reducing the discarded glass wastes.

The discussion is based largely on an article prepared by Dr. E. Joseph Duckett.²² Additional information was obtained through private communications with representatives of government, private industry and universities. (See Appendix A for a list of contacts).

DISCUSSION

The potential value of waste glass in construction materials depends on the value of the material it replaces and ancillary considerations such as energy requirements and accessibility to, and availability of, waste glass of the required quality.

22. "Glass Recovery and Reuse," Dr. E. Joseph Duckett, NCRR Bulletin, Vol. VIII, No. 4, Fall 1978.

Generally, the value of material replaced by waste glass in construction products is relatively low. This low value is reflected in the locations of manufacturing plants, i.e., many plants are situated near raw material sites, thus minimizing transportation costs. Waste glass, however, is largely generated in urban areas and, following recovery, would have to be shipped to the manufacturing plants, thereby incurring significant transportation costs in many cases.

It is estimated that waste glass recovered for use in roadbed construction would replace low-priced aggregate valued at \$2 - \$3 per ton. For use in bricks, added at a 10 to 20 percent rate, glass may be worth 2 to 3 times as much per ton. It should be noted, however, that transportation costs for waste glass may amount to \$5 to \$10 per ton or more, depending on shipping distances and freight rates.

Technical problems and costs are also incurred in the recovery and collection of waste glass. Technical problems can be largely circumvented by the separation of glass at the household level. Once glass has entered the municipal solid waste stream, however, relatively sophisticated processes are needed for separation and processing.

There are two techniques, froth flotation and optical sorting, that have shown promise for successful recovery of usable cullet.

Froth flotation is a minerals processing technique that has been adapted for use in waste glass recovery. Glass cullet recovered by froth flotation has been tested in laboratory melts. The cullet has been reported to be low in refractory particle content and to produce a glass product that is virtually free of inclusions. The process yields particles of color-mixed glass cullet in the size range of minus 20 mesh to plus 140 mesh. To date, no practical method for color-sorting froth-floated cullet has been developed.

The other approach for recovery of container quality cullet is optical color-sorting of glass particles larger than 6mm (1/4 inch) in size. Optical sorters, commonly used in food processing and other industries, have been modified for use in glass cullet recovery.

In practice, at least two types of sorting are involved: a separation of opaque (mostly nonglass) particles from transparent particles; and then a sorting of the transparent particles by color.

The significance of cullet purity and color separation depend on the end product in which the cullet is employed. For example, cullet used as lightweight aggregate has the least restrictions; cullet employed in the manufacture of certain types of glass containers may have to meet rigid specifications.

At present, there are no published specifications for glass to be used in brick manufacture. Important characteristics of glass for use in brickmaking include particle size and content of organic materials.

The effectiveness of glass as a fluxing agent in brickmaking has been shown to be a function of particle size. Glass ground to minus 200 mesh has been reported to reduce firing temperature by as much as 500°F (from a normal firing temperature of 2150°F) when used as 50 percent of the brick mix. The fluxing action of the glass is impeded by the presence of organic contaminants. A maximum of 10 percent organic material in the waste glass fraction has been proposed as the limit to assure fluxing action sufficient to lower firing temperatures by at least 100°F.

Theoretically, construction materials could absorb significant quantities of waste glass. From a practical point of view, however, there are a number of technical and economic obstacles which may inhibit its use on a significant scale, particularly in the near future.

Production processes designed to incorporate waste glass into construction materials are presently in various stages of development. Similarly, glass recovery systems are presently operative only as pilot plant operations. Their ability to generate cullet which meets the specifications for waste glass applicable for the various types of construction materials has yet to be proven.

The economics of employing waste glass in construction materials is marginal at this time. This arises from a number of factors, which include: the relatively low value of the virgin material replaced by the waste glass; waste glass recovery, processing, and transportation costs.

Potential benefits which may accrue from the employment of waste glass in construction materials are the reduction in the magnitude of municipal solid waste which must be disposed and energy savings in the production of selected materials, such as bricks.

Significant benefits, however, will only result if a large segment of the construction industry, both public and private, utilizes construction materials which contain waste glass.

POTENTIAL GUIDELINES

Product development has not reached commercial production of the construction materials under consideration. The promulgation of appropriate guidelines must await reasonably large-scale availability of the products in the market place.

Section 13

PLASTICS

INTRODUCTION

Plastics of various types are now widely used in the manufacture of products used in building construction. Major product groups include: flooring; glazing and skylights; insulation; lighting fixtures; panels and siding; pipe, conduit, and fittings; profile extrusions; plumbing fixtures; resin binded woods; vapor barriers; and wall coverings. In 1978, shipments of plastic building products totaled 3,159,000 tons.²³ The largest single product group in the building category was that of pipe, conduit, and fittings, which alone accounted for 1,473,000 tons, or 46.7 percent of the total. This product group was of direct interest in the present study. We estimate that public construction projects account for approximately 294,600 tons, or 20 percent, of the total amount of plastic pipe shipped annually.

Within the pipe group, polyvinyl chloride (PVC), high-density polyethylene (HDPE), and acrylonitrile-butadiene-styrene (ABS) accounted for over 90 percent of the shipments in 1978. PVC pipe alone accounted for approximately 67 percent of total shipments.

MANUFACTURE

The production of both PVC and HDPE requires ethylene, the major source of which is natural gas. For PVC production, ethylene is reacted with chlorine and hydrochloric acid to form ethylene dichloride, which is then cracked to form vinyl chloride and chlorinated organics. The vinyl chloride is then polymerized in an exothermic, self-sustaining chain reaction to form PVC.

In the production of HDPE, ethylene is fed to a reactor along with a catalyst and a diluent. The polymerized product forms as a powder. ABS is a compound of styrene-butadiene polymers, butadiene-acrylonitrile rubbers, and other compounding ingredients.

In the production of plastic pipe, resins mixed with stabilizers, plasticizers, lubricants and other additives are first dried and then passed through an extruder hopper and an extruder cylinder where they are melted. The pressure of the cylinder and a rotating screw force the mixture through the orifice of a die. After a sizing and cooling

23. Modern Plastics, p. 62, January 1979.

process, the pipe emerges and is then cut to length or coiled.²⁴

Plastic pipe as produced in the United States conforms primarily to standards developed by the American Society for Testing and Materials (ASTM). Other standards have also been established by the American National Standards Institute (ANSI), the National Sanitation Foundation (NSF), and the American Water Works Association (AWWA).

RECOVERY AND RECYCLING OF PLASTIC SCRAP²⁵

The recycling of home scrap and prompt segregated scrap is standard practice in the plastic industry. The successful recycling of scrap at this level is due primarily to the fact that the scrap is already segregated by type of plastic and/or is easily identifiable by type. The situation becomes more difficult, however, once the plastic scrap enters the waste stream. The cost of recovery and segregation is generally high and sometimes exceeds the salvage value of the scrap or the cost of virgin materials. It is noted that, historically, once the plastics leave the fabrication points, they have seldom been recovered. There are other reasons, in addition to cost, why the recycling of post-consumer plastic wastes has been limited, a major one being that resin properties and performance degrade through aging, during fabrication and in the reclamation process. However, new technological developments for upgrading plastic scrap may eliminate some of the present risks involved in recycling plastic wastes.

The Society of the Plastics Industry²⁵ identifies three main sources of plastic waste:

1. The plastics industry (producers of primary polymers) itself, which recycles part of its waste internally and sends the remainder for recovery and recycling to scrap processors.
2. Fabricators, who recycle most of their plastic wastes internally.
3. Industrial, commercial, and agricultural users, wholesalers and retailers, and private households, where waste is usually hauled away to municipal disposal sites near their location.

24. "Plastic Pipe: Profile of a Growing Market," K.L. Kollar and W. Youngwirth, Construction Review, March 1976, published by U.S. Department of Commerce.

25. Based largely on information contained in the "1978 Edition of Facts and Figures of the Plastics Industry," published by the Society of the Plastics Industry, Inc., 355 Lexington Ave., N.Y., N.Y.

Waste plastic from producers of primary polymers and fabricators, which is not reprocessed internally, is generally acquired by either scrap dealers or reprocessors. The function of the scrap dealers is generally limited to transferring the scrap from the producer to the user. The reprocessors, on the other hand, perform one or more operations on the scrap including regrinding, washing and reblending. Reprocessors frequently operate on a contract basis, returning the processed wastes to the organization from which they were obtained. In a contact with one scrap reprocessor, it was noted that because of recent increases in shipping rates for materials of low bulk density, such as plastic wastes, it has become too expensive to ship much useful plastic waste.

It has been estimated that in 1975, gross discards of solid waste derived from post-consumer and commercial sources amounted to 136 million tons.²⁶ Of this amount, 2.6 million tons, or about 2 percent, was plastic waste, little, if any, of which was recovered and recycled. One of the major difficulties in the recovery and reuse of such plastic waste is the fact that it is both contaminated and unsegregated by type. Industry studies²⁵ indicate that "...the use of waste plastics in an unsorted form for the recovery of energy will comprise the most successful plastics recycling program in the context of present-day technology and economics." This statement is qualified, however, with the observation that "...the technological and economic evaluations are still in a developmental phase."

In addition to the technical and economic factors that have inhibited the recovery and recycle of plastic waste, there are restrictions imposed by specifications that include prohibitions against the use of old plastic scrap. The National Sanitation Foundation has developed Standard No. 14 (revised February 1977) pertaining to thermoplastic materials, pipe, fittings, valves, traps, and joining materials. Section 4 of the Standard, entitled "Requirements for Pipe, Fittings, Valves, and Traps," reads in part as follows: "Thermoplastic pipe, fittings, valves, and traps shall be produced only from virgin materials meeting the requirements of this standard for the use intended. Clean rework material of the same virgin ingredients generated from the manufacturer's own production may be used by the

25. "1978 Edition of Facts and Figures of the Plastics Industry," published by the Society of the Plastics Industry, Inc., 355 Lexington Ave., N.Y., N.Y.

26. "Fourth Report to Congress, Resource Recovery and Waste Reduction," prepared by the U.S. Environmental Protection Agency, Office of Solid Waste, 1977 (SW-600).

same manufacturer provided that the finished products are equal in quality to products manufactured from virgin materials." (Underlines added). Because of specifications such as these, any manufacturer of plastic pipe is reluctant to use old scrap and thereby risk being eliminated from competition. The reasons behind such specifications are well founded and are based upon considerations of both product performance and integrity, and possible contamination of the product by undesirable components in waste materials. Contamination is a particularly important consideration for pipe used in the distribution of potable water. Following any future developments in the reclamation of plastic wastes that would make the use of recovered material acceptable for use in plastic pipe production, it would probably require several years before existing specifications would be modified to allow its use. A certain period of testing would be required, followed by the drafting and acceptance of amendments.

GUIDELINES

Opportunities for the development of government procurement guidelines for plastic pipe appear to be limited. In the course of discussions with various industry spokesmen, low-head irrigation pipe and corrugated agricultural drainage tubing were mentioned as two products that might be able to utilize waste plastic in their manufacture. However, subsequent investigations revealed that present standards prohibit the use of waste plastic in these products, as well, and that the potential use of plastic scrap in corrugated plastic drainage tubing was analyzed in detail in recent years. The findings indicated that the quality and standard of product performance could not be maintained on a consistent basis by pipe manufacturers. Even low percentages of scrap resulted in inferior (and unacceptable) quality in the final product. It was concluded that the only way that the use of scrap might prove successful would be to have the scrap returned to the plastic manufacturers for reclassification and blending with virgin material. Apparently no effort was made to implement such an approach. Similar considerations hold for plastic irrigation pipe.

Even if scrap plastic could be used successfully in the manufacture of irrigation pipe and agricultural drainage tubing, the impact on overall scrap consumption would probably be small. Reliable production figures for these two types of pipe apparently are not available. However, it is estimated that annual shipments of corrugated plastic drainage tubing total approximately 115,000 tons of which perhaps only 20 percent, or 23,000 tons, would be affected by government procurement guidelines. Requiring 25 percent recovered material use in the production of corrugated plastic drainage tubing for public-funded projects would result in the consumption of an estimated 5800 tons of plastic scrap. Scrap consumption in the manufacture of low-head plastic irrigation pipe would probably be of the same order.

In summary, plastic scrap that is segregated and uncontaminated is currently being recycled. Thus, most home scrap and prompt industrial scrap is recovered and reused. On the other hand, plastic scrap that is unsegregated and contaminated has little value as a raw material for the manufacture of plastic products. Accordingly, the recovery of plastic wastes from the municipal waste stream has proven to be neither practical nor economical. Until suitable technology is available for the recovery and reclamation of plastic scrap that is not now being recycled because of technical and economic reasons, it would be premature to develop procurement guidelines in this product category.

Appendix A

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Appendix B
LISTS OF INFORMATION NEEDS FOR GOVERNMENT AGENCIES
AND TRADE ASSOCIATIONS

A. CONSTRUCTION ACTIVITIES

1. Annual dollar value of all construction activities:
 Actual figures for years 1970-1977
 Projected figures for years 1978-1985
2. Types of construction (e.g., office buildings, roads, hospitals, residential)
3. Percent of total construction represented by each category listed in response to A.2 above

B. CONSTRUCTION MATERIALS

1. Categories of materials used in construction...see the eight general categories identified in Enclosure 1 (e.g., steel, aluminum)
2. Specific products used in construction...see specific products listed in Enclosure 1 (e.g., steel reinforcing bars, structural shapes)
3. Annual amounts of each product listed in response to B.2 above (Dollar value and/or weight, volume, or length as appropriate:
 Actual amounts for years 1970-1977
 Projected amounts for years 1978-1985
4. Trends (if any) toward new materials and/or products

C. PROCUREMENT PRACTICES

1. Level at which purchases of construction products are made (e.g., by the agency itself, by the prime contractor, by the subcontractors)
2. Level at which material/product specifications are incorporated into construction design
3. Procedures for insuring that material/product specifications are met
4. Existing procurement specifications that require, or allow the use of, "recovered material"* in construction products.

D. SPECIAL CONSIDERATIONS

1. Factors that make it difficult to introduce changes in procurement specifications for construction products containing recovered materials.
2. Time frame and procedures involved in revising procurement specifications to allow, or require, the use of recovered materials in construction products.

* "Recovered material" is any material which, after conversion into a finished product and utilization by a fabricator or final consumer, is collected or recovered. Home scrap (or revert scrap) does not fall within this definition, since such material is not recovered "after conversion into a finished product..." Prompt industrial scrap, on the other hand, does since it is material generated in fabrication operations.

DEFINITION OF RECOVERED MATERIAL

The term "recovered material," as used repeatedly in the following sections, refers to any material which, after conversion into a finished product and utilization by a fabricator or final consumer, is collected or recovered. Home scrap (or revert scrap) does not fall within this definition, since such material is not recovered "after conversion into a finished product..." Prompt industrial scrap, on the other hand, does since it is material generated in fabrication operations.

A. BACKGROUND INFORMATION

1. Types of construction products currently being made using "recovered material" (in whole or in part), or having the potential of being made using "recovered materials" in the 1978 to 1985 time frame.

The following information (B through J) is needed for each product or product category identified under A.1 above.

B. PRODUCTION INFORMATION

1. Annual U.S. production figures: actual figures, years 1970-1977
projected figures, years 1978-1985
2. Major producers (i.e., those producers whose combined production represents 80% or more of total U.S. production).
3. Percentage of total production that is used for construction projects funded fully or partially by the U.S. Government.
4. Percentage of total production by weight that contains "recovered material" in any amount. Percentage that contains home scrap.

C. MATERIAL INFORMATION

1. Total amounts and types of "recovered materials" currently being used annually in U.S. production. Also, total amount of home scrap being used.
2. For any product currently being made using "recovered material," the sources, types, and amounts (metric tons per metric ton of product) of "recovered materials" used (give ranges of values if appropriate). Also, the amount of home scrap used (metric tons per metric ton of product).
3. The maximum amount of "recovered material" that could be used in production without degrading the performance required for intended end use (metric tons of "recovered material" per metric ton of product).
4. The maximum amount of "recovered material" that could be used in production now without the need for major changes in equipment or processes. In 1980? In 1985?
5. Type(s) and amount(s) (metric tons per metric ton of product) of virgin material(s), replaced by the "recovered material(s)" for products currently being made.
6. Quantity of virgin material required when product is made solely from virgin materials (metric tons per metric ton of product).
7. The sources/suppliers of the "recovered material(s)" (e.g., municipal solid waste, scrap from fabricators, secondary materials dealers) and percentage of "recovered material" obtained from each.
8. Specifications for "recovered material" as it is delivered to the product manufacturer (e.g., maximum allowable levels of contaminants, size distribution, bulk density).
9. Experience with availability of "recovered material" required: delivery times; constancy of quality; steady supply; etc.

D. PROCESS/EQUIPMENT CHANGES

1. Changes in manufacturing processes required to allow use, or greater use, of "recovered materials."
2. Preprocessing or preparation of "recovered material" (as delivered) required to make it suitable for use.
3. Equipment required to enable "recovered materials" to be used, or used in greater quantities, in production.

E. COST INFORMATION (Ranges are acceptable)

1. Cost of "recovered material" as delivered to user.
2. Cost to preprocess or prepare delivered "recovered material" to make it suitable for use.
3. Capital costs of special equipment and facilities required to make possible the use of "recovered materials."
4. Incremental changes in production cost (or prices charged), for products made using virgin materials only and for products made using "recovered materials" only or a mixture of virgin and recovered materials.
5. Incremental effect on production costs (or prices charged) of increasing the percentage of "recovered material" contained in the final product, assuming that the capability to use "recovered material" already exists.

F. PRODUCT QUALITY

1. Effects (if any) of use of recovered materials on the overall "quality" of the final product. Strength, hardness, insulation value, durability, corrosion resistance, appearance, fire retarding characteristics, etc., as appropriate for a given product category.
2. Amounts of contaminants in recovered material that degrade product quality to unacceptable levels.

G. ENVIRONMENTAL-ENERGY CONSIDERATIONS

1. Effects on air and water emissions (and solid waste generation) caused by introducing recovered materials into the manufacturing process.
2. Incremental changes in energy consumption in manufacture due to increased use of recovered material(s).

H. CERTIFICATION

1. Means available for certifying that construction products delivered in any given shipment contain some minimum level of "recovered material(s)". (e.g., record of input materials for each production run; tests of selected samples from batch, etc.).
2. Possible alternatives for certification if it is not possible (or practical) to verify recovered material content of each production run (e.g., records of daily, weekly or monthly average values of recovered material content).

I. SPECIAL CONSIDERATIONS

1. Factors that have inhibited increased use of recovered material in the manufacture of construction products (e.g., cost, unavailability of recovered material having acceptable quality, reluctance in the market place to accept products made with recovered materials, inability to maintain satisfactory product performance).
2. Any government specification, standard or performance requirement of which you are aware that directly, or indirectly, discriminates against the use of "recovered material" in the end product.

J. SUPPLY/DELIVERY INFORMATION

1. Percentage of companies that currently manufacture products containing some level of "recovered material."
2. Names of companies included in response to J.1 above.
3. Incremental change in delivery time if specifications require that product be made using some percentage of "recovered material."

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